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Configuration management policy for the Naval Air Warfare Center Training Systems Division

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THESIS

**CONFIGURATION MANAGEMENT POLICY
FOR THE
NAVAL AIR WARFARE CENTER
TRAINING SYSTEMS DIVISION**

by

Raymond E. Hammond

March, 1995

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13. ABSTRACT *(maximum 200 words)*

Although there is a Configuration Management (CM) policy in place at the Naval Air Warfare Center Training Systems Division (NAWCTSD), it has not been implemented in a manner that standardizes CM across all weapons platforms and programs. Furthermore, CM requirements are not interpreted the same by all personnel required to implement CM for systems acquisition or during the systems' life-cycle support phase. NAWCTSD acquires and supports systems for Naval aviation, surface, and subsurface communities as well as other Government agencies.

This thesis presents the essential elements of a comprehensive CM policy and an implementation strategy that addresses the diverse customer base and diverse elements of NAWCTSD required to implement CM policy. It presents research about other Government agencies that have successfully implemented CM. Technical treatises were researched and pertinent information presented. Government regulations and military standards were researched to determine which regulations apply to NAWCTSD and to resolve potential conflicts arising from the interpretation of regulations and military standards. The impact of current acquisition streamlining efforts is presented and analyzed.

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CONFIGURATION MANAGEMENT POLICY FOR THE NAVAL AIR WARFARE CENTER TRAINING SYSTEMS DIVISION

by

Raymond E. Hammond

B.S., California State University, 1991

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I. INTRODUCTION

A. BACKGROUND

Although there is a CM policy in place at the Naval Air Warfare Center Training Systems Division (NAWCTSD), it has not been implemented in a manner that standardizes CM across all weapon platforms and programs. Furthermore, CM requirements are not interpreted the same by all personnel required to implement CM for systems acquisition or during the systems' life-cycle support phase. It is highly desirable to establish the minimum acceptable CM standards that all programs must meet.

It is anticipated that implementation of an effective acquisition CM policy at NAWCTSD will provide a base for the development and implementation of an effective CM policy for the life-cycle of acquired systems. Although life-cycle CM will be discussed in this thesis, the main thrust will be the determination of an effective acquisition CM policy for NAWCTSD.

The present CM policy at NAWCTSD is governed by NAVTRASYSCENINST 4130.3, dated 29 September 1993. It is presently under review for revision and will include information derived from this thesis as part of a planned revision scheduled to be performed annually. The instruction title will be changed to NAWCTSDINST 4130._M to reflect the new organizational title. NAWCTSD was previously the Naval Training Systems Center (NTSC). NTSC became NAWCTSD after the present NTSCINST 4130.3 was implemented. In this thesis the instruction will be referred to as the NAWCTSD 4130._M instruction to reflect the new correct name for the updated instruction.

Competency 1.3.2, the Program Support Competency, is the lead organization for configuration management at NAWCTSD. It is responsible for establishing CM policy and for insuring that consistent and acceptable CM is practiced in all programs under the cognizance of NAWCTSD. Competency 3.0 is updating and modifying the NAWCTSD CM instruction as an assist task to Competency 1.3.2. The NAWCTSD instruction is a derivative of the NAVAIRINST 4130.1C dated 31 January 1992. The implementation of NAWCTSDINST 4130._M will encompass overall CM policy and promulgate instructions and other directives and guides to all competencies required to implement CM policy.

Competencies 1.3.2 and 3.0 are not the only competencies with an interest in CM policy at NAWCTSD. Several other competencies are responsible for implementing CM policy either in conjunction with an acquisition (for new systems or upgrades to existing systems) or in conjunction with ongoing Life-Cycle Support (LCS). Outlying field activities, called In-service Engineering Offices (ISEOs), provide trainer system engineering support (modification) for hardware, software, and technical documentation as well as a variety of other trainer and training system support functions.

Competency 4.0, the Engineering Competency, and the ISEOs are responsible for acquisition support of training systems as well as hardware, software, and documentation status. They are also responsible for implementation of automated or other CM and Configuration Status Accounting (CSA) functions and systems in support of systems acquisitions efforts and their fielded systems.

Competency 3.0, the Logistics Competency, performs many support functions including support for systems acquisition efforts and is intimately involved in ongoing CM issues concerning "fielded" systems. "Fielded" in this context, implies that the system is no longer under the direct cognizance of one of the acquisition Project Managers (PJMs) as an acquisition oriented project. PJMs retain cognizance over the system for the life of the system, but the emphasis for system support changes from acquisition to LCS when the system is fielded. Within Competency 3.0, the Integrated Logistics Support Manager (ILSM), one of the Competency 1.0.X competency managers, will determine general CM requirements, CM data requirements, and CM audit requirements in consultation with the Project Manager (PJM).

NAWCTSD procures and supports systems which provide unique CM challenges. Most of the acquired and supported systems are complex state-of-the-art systems and are acquired in small numbers. Maintenance support is provided almost exclusively by contractors. Technical documentation accuracy and system concurrency with weapon systems or other platforms is crucial and will cover a span of many years dependent upon the weapon system. CM plays a major role in assuring that system changes are properly documented, that hardware and software changes are traceable to requirements, and that baselines are accurately represented in data management systems. Simply put, all documentation for both hardware and software must accurately reflect the current system configuration.

Systems acquired and supported by NAWCTSD are widely dispersed throughout the continental United States, Hawaii, Alaska, and in many foreign countries. Additionally, NAWCTSD serves many customers such as the surface, sub-surface, and aviation communities within the Navy as well as the Army, Air Force, Marines, and other Federal agencies.

A memorandum released by the Secretary of Defense, William Perry [Ref. 1], states that unless waivered, military specifications and standards will not be applied to the acquisition of new weapon systems. This has introduced an element of question in the implementation of CM based on MIL-STD-973 and other standards. If military standards are not to be used in the development of new systems, then the implementation of CM in a standardized fashion using MIL-STD-973, may not be a goal of NAWCTSD as a matter of policy.

It may be that NAWCTSD will rely on industry standards defined in individual contract definitions to implement CM. This question will be more thoroughly discussed in Chapter V, Analysis and Interpretation of Data.

B. RESEARCH AND SUBSIDIARY QUESTIONS

This thesis will address the following research question:

> What should be the essential elements of a configuration management (CM) policy for NAWCTSD acquisitions and how might this policy be implemented?

The following subsidiary questions will further define the problem and lead to a more complete analysis:

> What are the essential elements of CM policy and what are the requirements established by DoN, DoD, and other Federal Government regulations?

> What are the basic components of CM policies that exist for similar Government organizations and industry firms?

> What are the significant problems and issues associated with establishing a CM policy that is unique to NAWCTSD and how might these problems and issues be resolved?

These subsidiary questions will be further subdivided into sub-subsidiary questions as necessary to completely answer each element identified. This approach to problem solving, known as the dendritic approach [Ref. 2, p. 14-6], is diagrammed in Appendix A. The reader is invited to refer to Appendix A as needed to gain a picture of the complete problem description and proposed solution.

C. PROBLEM DEFINITION

The major problem is that CM is neither uniformly nor effectively applied in the acquisition and life-cycle support of training devices and equipment procured or accepted for support after procurement by NAWCTSD. The magnitude of this problem is reflected in the size of the inventory supported by NAWCTSD, which is approximately 2,500 trainers and training systems valued at approximately $3.5B located at 289 individual fleet and training units.

In an era of continuous downsizing of the armed forces, it is crucial that simulation systems and trainers be properly maintained and that the configuration of those systems accurately reflect the systems they support. CM, properly executed, can save potentially billions of Operation and Maintenance (O&M) dollars by improving system software and hardware maintenance and by reducing the need for operational equipment and personnel required to be used in training scenarios.

In some cases, an adequate CM system has not been established during acquisition. This can be problematic during the acquisition phase and may carry over into the operational system for its entire life-cycle. It is important that the process of CM be started early in the acquisition phase in order to assure that system baselines are accurate and fully documented at the time the system is accepted by NAWCTSD and the user. Such a CM system should be in place and workable prior to acceptance of the system by the Government.

The level (system, sub-system, sub-sub-system...), methodology (automated, manual, combination of both), and systems (training devices, technical documentation) on which CM is to be performed is not as clearly defined in existing instructions and guidelines as some personnel would prefer.

Competency 1.3.2 is responsible for overall CM policy (writing instructions, defining scope, defining methodology, etc.). Other competencies within NAWCTSD are responsible for implementing that policy. It is not clear, therefore, what role each of the implementing competencies, including acquisition competencies, will play in establishing or actually performing CM on systems and technical documentation. Nor is it clear what the needs of each of those competencies are with respect to CM. The role of contractors and their performance of CM during the system's operational phase should also be clearly defined.

These problems, in the aggregate, have prevented the effective implementation of CM across the broad spectrum of NAWCTSD supported and acquired devices. It is evident that CM is being performed, but the evidence indicates that it is spotty, that there is no unified data management regarding reporting systems, that different competencies interpret the level to which CM is to be performed differently. This may be caused by the diverse customer base and because NAWCTSD is managing many unique and totally different configuration items. These problems result in inefficiencies in the overall system.

It should be noted that differences in the method of performing CM and the level to which it is to be performed may differ between training systems and their respective communities. The core CM effort at NAWCTSD needs to be standardized and a standard approach to accomplishing CM across all supported communities and devices should be established. In this context "core" means CM procedures and methods used by NAWCTSD in support of oversight CM functions that support all Cognizance 2"O" systems. An example of this would be the functions of the NAWCTSD Trainer Engineering Change Control Board (TECCB) and the central status accounting system used to document multiple configuration items which span all systems supported by NAWCTSD.

It is evident that different competencies perform the functions of CM differently. Different CM systems are being used (and this will likely continue to be the case for the reasons stated in the previous paragraph). Some of the different types of physical systems include fully automated (mainframe, mini-computer, or PC), semi-automated, semi-manual depending upon the emphasis, manual, or partially implemented systems that simply document the system or item according to device number, nomenclature, and serial number (essentially no more than inventory maintenance). There are also different technical approaches to CM based on the individual program or system. It is not the difference in systems that is important, it is the difference in the methodology, level, and types of reporting and documentation that must be studied and, if necessary, changed to improve the overall accomplishment of NAWCTSD core CM in a standardized fashion and of approaching development of CM systems in support of different platforms, weapon systems, and communities served by NAWCTSD.

Records which document baselines and configurations, whether digital or hard copy, are not standardized, are difficult to understand across all platforms, and do not share common data elements. Traceability from requirements to system configuration (including the configuration that results after modification to the system) is, in some cases, spotty or non-existent and is not in a standardized format. Digital information cannot be shared universally.

A standardized approach to CM will make reporting simpler and will facilitate better communications across Service or agency borders. CM, if not properly performed may result in situations where a weapon platform may not be accurately modeled by the simulation system. In those cases training can have a detrimental effect. The problem is mitigated if system users know the exact configuration of the system so that system differences can be identified in the training scenario.

Differences may be such that the system is degraded over that being used in the fleet. In some cases systems may be upgraded prior to fleet release of the upgrade or modification. Whichever the case, it is imperative that the exact system configuration be known to the users of the system.

D. SCOPE

The main thrust of this thesis will be to determine the essential elements of a CM policy for NAWCTSD and to provide recommendations for implementing a CM policy at NAWCTSD. The thesis will include a study of at least one example of effective (successful) CM policy implementation at at least one Government organization and one industry firm.

E. LIMITATIONS

This thesis will not include a recommended method of internal NAWCTSD review for the recommended CM policy at NAWCTSD. The thesis will not include details of implementation for any specific program or acquisition being supported or conducted at NAWCTSD nor will it consider implementation with respect to any individual branch or other organizational unit having CM responsibilities unique to a specific program. Rather, the recommended policy will include the essential elements of a comprehensive CM policy implementation with a view to the overall policy of NAWCTSD and its CM requirements with respect to existing Government regulations. Recommendations concerning organizational elements and individual responsibilities for overall CM implementation will be included.

This thesis will not attempt to explain the technical details of CM as practiced. Rather, it will concentrate on overall CM policy elements and implementation. Technical explanations concerning automated or manual CM systems will be only generally discussed or referenced. Technical explanations will be kept to an absolute minimum in order to facilitate easy reading by an audience which may not be familiar with the technical aspects of CM.

F. ASSUMPTIONS

It is assumed that the reader is generally familiar with the concepts of CM as practiced in both Government and civilian organizations. It is assumed that the reader has ready access to Government instructions, written policy, supplemental written material, and other references listed in the list of references. It is also assumed that the reader has sufficient technical background to independently analyze technical material presented but not explained in the body of the text as it refers to CM issues such as that covering the acquisition of software and hardware.

G. LITERATURE REVIEW AND METHODOLOGY

There is a large body of current literature from which to conduct research concerning CM theory. This thesis is not so concerned with CM theory as it is with the successful implementation of CM policy at NAWCTSD. Therefore, the literature searched will be to synthesize information gleaned from an agglomeration of general information concerning CM policy and specific information concerning the successful implementation of CM policy at one comparable Government entity and at one comparable industrial organization. The methodology employed involves data searches at the NPS library, research of Government regulations and instructions including NAWCTSD and NAVAIR instructions and implementing guidelines and instructions from other Government agencies and industrial firms. Additionally, Government representatives from various agencies and from civilian institutions will be interviewed to determine how CM policy was initiated at their respective organizations or in their acquisition programs and the success of the CM policy implemented.

H. DEFINITIONS AND ACRONYMS

Appendix B provides a Glossary of Acronyms used in this thesis. See Appendix C for definitions of terms. These definitions were derived from NAWCTSDINST 4130._M, Appendix A, NAVAIRINST 4130.1C, Appendix A, and DoD Instruction 5000.2.

I. ORGANIZATION OF STUDY

The seven chapters of this thesis are organized in such a manner that they present a logical progression from problem statement to conclusions and recommendations. The inclusion of Appendix A, a dendritic analysis, is key to the development of a satisfactory conclusion and recommendations describing the essential elements of a NAWCTSD Configuration Management Policy. It is key because it represents the whole of the problem in a graphical format that is easy to understand. The organization of the thesis complements the organization of the problem as presented in Appendix A and facilitates development of matrices which cross reference answers to questions and data.

II. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

A. STRUCTURAL FRAMEWORK

The structural framework for this thesis is based on a study of successful implementation of CM policy at a Government and industry organization as well as a comprehensive search of current DoD, DoN, and other Government instructions, specifications, and standards. Personnel from other Government agencies and from industry firms which have successfully implemented CM under a CM policy were interviewed and provided a rich resource of information concerning the essential elements of a CM policy and current theoretical knowledge of CM. During the period this thesis was being written, the Perry Memo [Ref. 1] began to have a significant effect on the implementation of CM policy within the acquisition community. As much as possible, research conducted, and the structural framework of this thesis, includes up-to-date policy that encompassed changes made to accommodate the paradigm shift in acquisition policy mandated by the Perry Memo [Ref. 1].

The National Aeronautics and Space Administration (NASA) was selected as a comparable Government organization to study for its CM policy on the Shuttle program. The Shuttle program represents a large and complex system under effective hardware and software configuration management and control. This thesis will study information derived from NASA's software and hardware CM policy (See Appendix D) as it relates to development of the complex shuttle hardware and software development, modification, and life cycle support.

Loral Corporation, the Shuttle software development contractor, was chosen as a comparable industry organization for study of its CM policy. Loral, Incorporated was a good choice for an industry firm because part of the Loral success story in CM is a result of the CM policy in place at the NASA.

The implementation of a successful CM policy at Loral (Loral's own policy, not the NASA CM policy) for software work done on the Shuttle system under contract to NASA serves as a good industry model for design of similar CM policy implementations in other organizations, including Government organizations.

Loral was chosen because it represents a highly successful software development company involved in a highly successful, very complex, software development effort supporting the shuttle. The shuttle software development process, at Loral in Houston TX, was rated at a Level Five Software Process Capability Maturity [Ref. 3], the highest level achievable, after a process assessment conducted with the assistance of the Software Engineering Institute [Ref. 4, p. 81, par. 1.4.1].

This thesis is being written with an emphasis on DoD CM policy and issues; therefore, the U.S. Army's ATACMS-BAT program was studied and will be referenced as an additional comparable Government organization with a proven, successful, CM policy.

Research done on CM policy will address both acquisition and life-cycle issues as part of the structural framework. Theoretically, effective implementation of CM for the life cycle begins early in the acquisition phases.

Other areas of research in the structural framework that are applicable to solving the problem of developing and implementing a successful CM policy at NAWCTSD are contained in numerous management and organizational treatises and in DoD, DoN and other Government instructions and specifications. These were studied to determine what is required statutorily and what is simply recommended They were also analyzed to determine the hierarchical nature of the instructions and specifications governing CM policy, the recommended managerial policy from a "best practices" perspective, and the technical requirements of a CM policy.

Another part of the structural framework is in the area of standardization and program integration across a wide variety of platforms serving multiple customers. Policy was studied to determine if a competency aligned organization, such as NAWCTSD, can successfully integrate efforts and standardize on procedures effectively based on existing Government policy. Standardization of the CM process itself is studied to determine the extent to which CM policy should strive to standardize processes and policy.

Attention is also given to the involvement of upper management in the success of CM policy implementation.

B. KEY FACTORS AFFECTING IMPLEMENTATION OF CM

Following are the key factors affecting implementation of an effective CM policy at NAWCTSD:

1. Determination of the essential elements of CM to be performed by NAWCTSD for the entire life cycle of each type of system under its cognizance. Those systems represent the full spectrum of training devices from simple electro-mechanical systems to complex simulators such as the F/A-18 Flight Simulator. In some cases there are a large number of trainers comprising a system, such as at a Navy "A" school. In other cases there may be only one or two or up to ten simulators to support a system such as the F/A-18 Flight Simulators.

2. Determination and agreement of the principal elements of CM across a wide spectrum of disciplines and across a diverse number of organizational competencies at NAWCTSD.

3. Integration of the efforts of individuals within the organizational competencies at NAWCTSD.

4. Written interpretation of a specific set of rules, directives, and regulations concerning implementation of CM within the Government that pertain to NAWCTSD.

C. CAUSAL RELATIONSHIPS

There are a number of causal relationships that exist among the key factors that impact on the effectiveness of CM policy implementation at NAWCTSD. One significant relationship is the impact that the organizational structure of NAWCTSD imposes on the requirement that CM be implemented in a "standardized" fashion. Customers of NAWCTSD comprise elements of the surface, sub-surface, aviation, and intelligence communities within the Navy. NAWCTSD also acquires training systems and provides LCS for those training systems for the Marine Corps, the Air Force, the Coast Guard, and other Federal agencies. Support for Cog 2"O" systems is shared over several competencies within NAWCTSD such as Project Direction/Management, Contracting, Engineering, and Logistics. The efforts of these and other individual competencies must be integrated over the life of the systems in order to assure effective and efficient CM. Therefore, there is a causal relationship concerning internal organizational responsibility and overall control of the CM processes and systems. Which internal organizations will determine CM policy and which internal organizations will implement that policy? How will the needs of multi-service customers be made known to those in charge of policy development? Each of these questions has a cause and effect centered around the overall organizational structure. These relationships are complicated by the diverse, multi-service, multi-agency customer base.

There are causal relationships relating to Government instructions and directives on CM and the individual interpretations of the requirements for CM based on those instructions and directives. This problem is especially profound given the multi-service nature of the CM systems that must be implemented. CM concepts become mixed when viewed from the perspective of a multi-service environment.

D. CONTRIBUTIONS OF THIS THESIS TO THE GENERAL BODY OF KNOWLEDGE

This thesis reviews the general body of knowledge concerning the essential elements of CM policy and implementation of CM policy for organizations acquiring and supporting complex, one-of-a-kind or few-of-a-kind systems. It also provides a road map for implementing CM in a multi-service environment and within the organizational framework of a competency aligned organization.

It addresses CM implementation and effective standardization issues in a diverse organizational climate.

III. BACKGROUND OF CM ISSUES AT NAWCTSD

A. BRIEF HISTORY OF CM AND CM POLICY AT NAWCTSD

NAWCTSD is designated as an Office of Primary Responsibility (OPR) per NAVAIRINST 4130.1C. This designation carries with it certain responsibilities. Those responsibilities are to:

(1) Provide CM of assigned configuration items throughout their life-cycle.

(2) Prepare and maintain CM plans for assigned configuration items, obtaining approval of those plans, and assuring proper implementation of NAVAIRINST 4130.1C.

(3) Manage and provide direction for the staffing of all engineering change proposals, related weapon system engineering change proposals, Trainer Engineering Change Proposals (TECPs), and requests for major and critical deviations and waivers from initiation until submittal to the Trainer Engineering Change Control Board (TECCB).

(4) Implement TECCB directed actions.

(5) Maintain the status of implementing actions for approved engineering changes, deviations, and waivers.

(6) Conduct audits and establishing baselines.

(7) Establish and maintain an adequate configuration status accounting system.

NAWCTSD has complied with the requirements listed above by issuing instructions which implemented those requirements. NAWCTSDINST 4130._M is the latest instruction issued. Prior to the issuance of the NAWCTSDINST 4130._M there were a series of NTSCINST 4130.X implementing instructions. Each of those were issued in compliance with updated instructions from NAVAIR. To date, that sequence of instructions has been sufficient to provide a measure of success in accomplishing configuration management and control over the inventory of Cognizance Symbol 2"0" equipment.

NAWCTSD, under several different names since it became the Navy's premier training devices center in the mid 1940s, has supported its inventory of devices in an excellent manner. The necessity for formulating a more coherent CM policy is not because NAWCTSD has failed to accomplish its assigned responsibilities with regard to CM, but because it is necessary to upgrade its capabilities to conform to more stringent demands from customers both internal and external to NAWCTSD and from rapid changes in technology.

NAWCTSD is faced today with the same problems of most industries. That is the problem of attempting to keep abreast of what could only be termed revolutionary changes in technology. Up until the early 1980s the major cost of training systems was in the hardware. In fact, hardware comprised the bulk of the system. Software was a lesser cost item though, even at the outset, managing software presented new and unique challenges especially with respect to configuration management and configuration status accounting. Today, the major cost of systems is in the development and maintenance of the software which comprises the bulk of the system's capabilities.

This situation presents system developers with the problem of performing configuration management on both hardware and software and of integrating that effort. This has required immense change and flexibility in CM technology, methods, and processes. All systems developers are faced with these changes and are attempting to respond.

NAWCTSD is currently in the process of updating and implementing CM instructions and policy because of the many changes that have and continue to take place in technology, methodology, and requirement for CM. Added to those changes, during the recent past there has been a revolutionary change in DoD acquisition policy. The recent memorandum on acquisition reform by the Secretary of Defense will likely result in additional changes in CM policy at NAWCTSD.

B. UNIQUENESS OF THE NAWCTSD CM EFFORT

The uniqueness of the NAWCTSD CM effort cannot be overemphasized. As mentioned previously, NAWCTSD serves many customers. Although NAWCTSD is an integral part of the NAVAIR team and is functionally under the direction of NAVAIR, it is also an integral part of the surface and sub-surface Navy. For many years NAWCTSD, under different names, was functionally under the direction of several different Navy Systems Commands but still always provided services to the many different Navy commands on both coasts. They also provided and continue to provide services to the Marine Corps and other military Services and did so long before "jointness" was a buzzword. At this time, NAWCTSD is working closely with NASA under a Memorandum of Agreement (MOA) and has ties with other non-DoD agencies. This has made the problem of implementing CM in a standardized fashion immensely difficult.

Within the Navy alone, the surface differs from the sub-surface Navy, both of which differ from the aviation part of the Navy on a number of issues concerning documentation, training, systems procurement, and life-cycle support. There are differences between Services and between non-DoD agencies in their requirements for documentation, training, systems procurement, and life-cycle support issues.

Additionally, NAWCTSD may be tasked to provide life-cycle support, including CM, on a device procured by another agency and then inducted into the NAWCTSD inventory as a Cognizance 2"0" device or system.

In the aggregate, NAWCTSD is faced with a unique challenge in performing CM both during acquisition and after acceptance by the user agency simply because of the many differences in the wide variety of customers serviced by NAWCTSD. This challenge cannot be overlooked in the development and implementation of any over-arching policy, such as a CM policy.

Added to the difficulties of multiple and diverse customers, is the diversity in the products delivered by NAWCTSD. The product may consist of an immensely complex, one-of-a-kind or few-of-a-kind device. Or it may consist of a less complex device procured in larger numbers but widely distributed. It is the diversity of the types of devices and their distribution that adds greatly to the complexity of establishing effective CM over a given device.

As an example of a complex, few-of-a-kind device, the F/A-18 trainer suite consists of number of weapon tactics trainers which are immensely complex and include a state-of-the-art visual system. The suite also includes a number of operational flight trainers, somewhat less complex than the weapon tactics trainers, but does still have a visual system. The last part of the suite consists of several part task trainers, which are the least complex but by no means simple systems.

All of the systems in the trainer suite rely heavily on digital technology and are driven by huge sophisticated software routines. The systems are widely distributed throughout the United States and overseas in several locations. They were procured over a period of approximately ten years and thus represent a large disparity in technology from the first to the last system procured. Several of the weapon tactics trainers were procured by NAVAIR with an assist task from NAWCTSD but all are Cognizance Symbol 2"0" systems for support purposes.

The F/A-18 aircraft has undergone evolutionary modifications since it was introduced into the fleet, and it continues to undergo upgrades and modifications to both software and hardware. All of these modifications have to be incorporated into the F/A-18 trainer suite, if applicable, and must be tracked for CM purposes both by the organizations responsible for the aircraft baselines and by the organizations responsible for the trainer suite baselines.

As can be seen from a description of the F/A-18 trainer suite, the problem of performing CM on that system is immensely challenging from a number of perspectives. It is a challenge because of the number of different versions of the system in existence. It is a challenge because NAVAIR procured some of the systems and NAWCTSD procured some. The systems are widely distributed geographically and this adds to the problem of effective configuration management and control since each system's baseline must be completely and accurately documented. The requirements for changes to the systems must be tracked from aircraft changes as well as possible changes to the simulation systems due to evolutionary development or latent problems in either software or hardware. Even changes in training doctrine or tactics from the operational side of the house must be documented and tracked.

IV. METHODOLOGY

A. RESEARCH DESIGN

Research for this thesis will be conducted using Appendix A as a road map. The dendritic approach outlined in Appendix A provides a breakdown of the critical issue into sub-objectives which are further broken down into sub-sub-objectives as needed.

The initial stages of the research involved a comprehensive analysis of the literature identified in the literature search as applicable. Proceeding from that analysis several of the subsidiary research questions were answered. As an example, the principal elements of CM policy and requirements established by the DoN, DoD, and other Federal Government regulations were clearly identified and catalogued according to their order of precedence. Which regulations, instructions, and directives apply to the NAWCTSD CM effort and which are subordinate or superior were identified.

A review of the NASA, Loral, and ATACMS-BAT, CM policies was performed to clarify the direction taken by those organizations to determine their best CM policy. This approach to solving some of the subsidiary questions is appropriate simply because not all of the answers to determining the essential elements of CM are contained in DoD and DoN regulations. A study of similar organizations helped clarify which policy elements were critical, and, equally important, which ones worked best to successfully implement CM.

One visit was made to NAWCTSD to discuss implementation policy with Competency 3.0. Competency 3.0 provided a draft of the proposed changes to the existing CM instruction, NAWCTSDINST 4130._M and clarifying remarks concerning the present status of CM implementation at NAWCTSD. No formal questionnaires were developed or used at the initial meeting with Competency 3.0 personnel since the author is familiar with the problems and personnel and only required an update on the status of the new instruction being developed.

Other NAWCTSD personnel were interviewed to get a flavor for the organizational problems involved in implementing an effective policy. Notes resulting from those interviews was used in the overall analysis of the data. No formal questionnaires were used.

Personnel responsible for CM policy and implementation from NASA, Loral, and the ATACMS-BAT program office were interviewed over the telephone. Information concerning their policies was obtained. Pertinent information is contained in Appendices D, E, and F and was used to supplement information contained in referenced texts, instructions, and specifications.

Several personnel who practiced CM at the grassroots level of the organizations involved in this study were interviewed. Thus, the author gained a working level perspective of the effectiveness of implementing CM policy.

The information derived was used to enhance development of policy for NAWCTSD.

B. ANALYTIC STRUCTURE

Analysis of the data derived from the applicable literature and interviews was used to develop a data matrix which linked data sources to items to be studied. From that matrix, it was decided which subsidiary research questions could be completely and adequately answered from the literature, instructions, specifications, and technical documents available and which required a more heuristic approach by developing answers based on the study of other successful CM policies and the interviews conducted. Key to the successful completion of this thesis is contained in

Appendix A. Appendix A provides a sufficient breakdown of the critical issue, the research question, to assure a comprehensive answer to all of the subsidiary research questions. Questions asked during interviews and answers to those questions were analyzed and included in the matrix described in the preceding paragraph. Analysis of those questions and answers is expected to contribute significantly to the body of knowledge to be developed as a result of this study and to a more "practical" solution to the research question.

The results of the analysis are the identification of the essential elements of a CM policy and recommendations necessary to implement a CM policy at NAWCTSD. Careful scrutiny of Appendix A assured that all relevant and important issues were addressed and questions answered.

V. PRESENTATION OF DATA

A. INFORMATION DERIVED FROM LITERATURE SEARCH

The following paragraphs present information derived from searching Government regulations, instructions, standards, and other pertinent literature concerning CM. The facts presented in this chapter will be analyzed in Chapter VI. All information is referenced to allow the reader easy access to source documentation for further study if desired.

Only the information concerning CM policy or implementation of that policy is presented. Only the most important facts are presented in the interest of readability and brevity. Information is organized by several of the most useful sources. Each sub-section below provides information from the source listed in the sub-section title. Within sub-sections, additional references are provided as appropriate. A wealth of information was derived from the "Military Project Management Handbook," other sources of information in the remaining sections do not contain information that was a repeat of information contained in Section 1 covering the "Military Project Management Handbook."

1. "Military Project Management Handbook"

Sources of regulations concerning CM are found at both the Department of Defense (DoD) level and at the Service level. Following is a list of sources [Ref. 5, p. 8.2]:

DoD Instruction 5000.2, Part 9, Sections A and B, "CM and Technical Data Management"

DoD-STD-100, "Engineering Drawing Practices"

DoD-STD-2167A, "Defense Systems Software Development"

DoD-STD-2168, "Software Quality Assurance"

MIL-STD-480B, "Configuration Control - Engineering Changes, Deviations, and Waivers"

MIL-STD-973, "Configuration Management"

MIL-HDBK-61, "Configuration Management" (aids in the implementation of Draft MIL-STD-973)

IEEE Standard, 828-1983, "IEEE Standards for Software CM Plans"

NASA Technical Memorandum 85908, "Software Control and System Configuration Management: A Systems-Wide Approach"

The above sources are not inclusive of all sources referenced in this thesis; they are the sources listed in the Military Project Management Handbook.

Configuration management is different from configuration control. (See Appendix C for definitions of each.) Configuration management is a set of processes which have specific product relationships. Configuration control is a generalized process. [Ref. 5, p. 8.3]

DoD-STD-2167A is concerned with software development and therefore does not consider configuration management in a system-wide context as do many of the other sources used in the research phase of this thesis. However, many of the same principles apply to both hardware and software CM. This thesis will consider the facts derived from DoD-STD-2167A whenever those facts may be considered appropriate to the development of overall or system-wide CM policy.

Configuration Management for both hardware and software begins at the time of contract award. The Government's configuration management plan should be developed early in the concept exploration and definition life-cycle phase, and should be updated at the beginning of each succeeding phase to reflect changing requirements. [Ref. 5, p. 8.4-5] The Government CM plan and the contractor's CM plan should, as a minimum, be coordinated. [Ref. 5, p. 8.5] The contractor CM plan should have separate sections detailing the contractor's process and procedures for configuration identification, configuration control, status accounting, subcontractor/vendor control, configuration audits, and life-cycle phasing considerations. [Ref. 5, p. 8.6]

In managing the process and activities of CM, it is necessary that the requirements and provisions of the contractually imposed standards be incorporated into subcontractor statements of work (SOWs), including all elements of a comprehensive configuration management program. [Ref. 5, p. 8.4]

The configuration change control process used by the contractor must [Ref. 5, p. 8.4]:

1. Ensure effective control of all configuration items and their approved configuration identifications.

2. Propose engineering changes to configuration items, request deviations or waivers for pertinent items, prepare software change notices (SCNs), and prepare notices of revision (NORs) on the appropriate form. The NOR is used only for proposing changes to documentation which required revision after engineering change proposal (ECP) approval.

3. Establish a developmental configuration for each software configuration item.

4. Maintain current copies of deliverable documentation and code.

5. Provide the contracting agency access to documents and code under configuration control.

6. Control the preparation and dissemination of changes to items under configuration control so that they reflect only approved changes.

Changes to configuration items which have been placed under configuration control, by the contractor, are accomplished by submitting requests for waiver, deviations, NORs, and SCNs [Ref. 5, p. 8.5].

Interface management, especially on large systems, may be handled by a separate interface or integration contractor. The prime development contractor's CM plan is required to describe either the contractor's interface identification and control, or the separately administered interface management program. [Ref. 5, p. 8.5] Contractor CM plans are delivered as a contract deliverable (CDRL) item subject to Government approval. [Ref. 5, p. 8.7]

One of the specific standard requirements for a CM plan is to address, as a minimum, the configuration control, interchangeability, and interoperability for all Non-developmental Items (NDIs). [Ref. 5, p. 8.7]

DoD Instruction 5000.2 sets policy to be followed by the program manager; whereas the various standards establish the requirements for implementing that policy. Standards, not DoD directives and instructions, are imposed on contractors as contractually binding requirements documents to the extent specified in the acquisition documents. It is important that DoD directives and instructions not conflict with DoD standards since standards are imposed on contractors. [Ref. 5, p. 8.8-9]

Most systems are composed of one or more configuration items. A configuration item may be hardware or software, and it may be decomposed into lower-level sub-elements. Configuration items are classified as prime item, software item, critical item, or non-complex item [Ref. 5, p. 8.14]. Prime items are documented with type B1 and C1 specifications. Software items are documented with type B5a, C5, or B5b specifications. Critical items are documented with type B2 and type C2 specifications. Non-complex items are documented with type B3 and C3 specifications [Ref. 5, p. 8.14-8.15]. (See the section labeled MIL-HDBK-61 for additional information concerning configuration identification.)

Firmware can be treated in configuration management as:

1. Non-developmental hardware and software.

2. Non-developmental hardware and Government-developed software.

3. Government-developed hardware and non-developmental software.

4. Government-developed hardware and software.

Each of these different mixes must be understood and both identified and controlled in light of their unique nature. This may mean references to the firmware identifications in either software specifications and drawings or hardware specifications and drawings or both. [Ref. 5, p. 8.15 - 8.16]

The Government must be careful to invoke the level of configuration management necessary for the contract in the statement of work (SOW). The SOW must identify the importance of the configuration management activity, and must describe the configuration management requirements in a separate and clearly identified section on the same level as other major development and management activities. [Ref. 5, p. 8.16]

The SOW should state how the Government will interact with the contractor on the configuration management program. This will include whether or not the Government will chair technical review meetings, attend change control board (CCB) or software change control board (SCCB) meetings, attend interface control working group (ICWG) meetings, and conduct periodic audits of the configuration management system and specifications during the project. [Ref. 5, p. 8.16]

2. DoD Directive 4245.7-M

This directive, titled "Transition from Development to Production," discusses the importance of configuration control in reducing risk in a program. It denounces the direct application of boilerplate policies and invoking military specifications which lead to ineffective control or overly complex and costly approaches to managing configuration. Many problems can be avoided by implementing a good configuration control system. A poor configuration control system leads to many pitfalls such as an unknown design baseline, excessive production rework, poor spares effort, stock purging rather than stock control, and an inability to resolve field problems. Poor configuration control is a leading cause of increasing program costs and lengthening procurement schedules. [Ref. 6, p. 3-30] A comprehensive CM policy will address the implementation of a configuration control system.

3. NAVAIRINST 4130.1C

This instruction, titled "Naval Air Systems Command CM Policy," implements SECNAVINST 4130.2 (referenced in NAVAIRINST 4130.1C). SECNAVINST 4130.2 will not be covered in this chapter since the interpretation of that instruction is embodied in the NAVAIRINST 4130.1C. NAVAIRINST 4130.1C establishes policy and assigns responsibility for CM. It also provides guidance for processing change proposals. It discusses CCBs and their structure and authority. The information presented in this subsection will concentrate on general CM policy rather than on detailed process guidance. NAVAIRINST 4130.1C is relevant to determining CM policy for NAWCTSD since NAVAIR is in the administrative chain of command for NAWCTSD.

NAVAIR has designated NAWCTSD as an Office of Primary Responsibility (OPR). An OPR is assigned primary responsibility for system acquisitions. A designated OPR has certain authority and certain limitations regarding CM as provided in NAVAIRINST 4130.1C. Authority and limitations relevant to CM policy will be discussed in this subsection.

Most of the information presented in this subsection is quoted directly from NAVAIRINST 4130.1C. Although this information could simply be referenced, it is felt that readability of the overall thesis is improved by including the information in the body of the thesis. This both emphasizes information and limits it to that which the author felt was most important in determining CM policy. NAVAIRINST 4130.1C, because of its importance in determining CM policy for NAWCTSD is critical in defining what that policy should encompass.

It is the policy that Class I engineering changes and major or critical deviations will be implemented only upon approval of a CCB. Rapid Action Minor Engineering Changes (RAMECs) will not be implemented prior to CCB approval. Configuration control requirements are to be included in acquisition documents per NAVAIRINST 4275.3F, "Implementation of Configuration Control," MIL-STD-480B, and MIL-STD-481. [Ref. 7, par. 4, p. 1]

OPRs are responsible for [Ref. 7, par. 6.a, p. 2]:

1. providing CM of assigned Cis throughout their life cycle;

2. preparing and maintaining CM plans for assigned CIs; obtaining approval of these plans, and assuring proper implementation of NAVAIRINST 4130.1C;

3. managing and providing direction for the staffing of all engineering change proposals, RAMECs, and requests for major and critical deviations and waivers from initiation until submittal to a CCB;

4. implementing CCB directed actions;

5. maintaining the status of implementing actions for approved engineering changes, deviations, and waivers;

6. conducting audits, establishing baselines; and

7. establishing and maintaining an adequate configuration status accounting system.

The Configuration Management, Program Policy and Resources Division (AIR-100) has the authority to enforce NAVAIRINST 4130.1C. It also governs the CCB for the Commander, Naval Air Systems Command. AIR-100 governs the operation of ALL (author's highlight) existing CCBs and has the authority to charter subordinate CCBs. AIR-100 also has the authority to review and approve OPR CM plans. [Ref. 7, par 6.b, p. 2,3]

Following are policy elements concerning CM during the acquisition phase [Ref. 7, par. 1.4, p. 1-1 - 1-2]:

1. Concept Exploration and Definition (CE&D) Phase. Initial CM plans are formulated and the functional baseline is established.

2. Demonstration and Validation (DEMVAL) Phase. CM plans are revised, functional baseline is updated, allocated baseline is established.

3. Engineering and Manufacturing Development (EMD) Phase. CM plans are revised and functional and allocated baselines are updated.

4. Production and Deployment/Operations and Support Phases. CM plans are revised, functional and allocated baselines are updated by a functional configuration audit, product baseline is established by a physical configuration audit, and the configuration status accounting record is coordinated with operating and support activities.

When more than one Government activity is involved in the development, acquisition, modification, or support of a configuration item, a mutually approved CM plan will be included as part of the program interface agreement [Ref. 7, par. 1.5, p. 1-2].

The OPR will ensure that each contract for a CI contains appropriate provisions for CM plans, CI, CC, configuration audits, and CSA documents as outlined by NAVAIRINST 4130.1C [Ref. 7, par. 1.6, p. 1-2].

If an OPR has more than one CI under its management, the use of an umbrella CM plan is recommended. An umbrella CM plan addresses the overall CM organization and planning which will be used. A separate addendum may then be prepared for each assigned CI explaining and further tailoring specific policies and procedures to be followed to accomplish CM of the item. [Ref. 7, par. 2.2.2, p. 2-2] The author could not find reference to other organizations outside of the DoD.

Separate CM plans will be required from each contractor who is developing and supplying hardware and/or software to the Navy. The OPR will assure that contractor CM plans are consistent with its own CM plans, NAVAIRINST 4130.1C, and with the total program needs. [Ref. 7, par. 2.3.1, p. 2-2]

The OPR will schedule and conduct functional and physical configuration audits following MIL-STD-1521B. Normally, due to the nature and criticality of configuration audits, they will be performed by Government personnel. [Ref. 7, par.4.3, p. 4-1] The reader is invited to review Figure 4-1, page 4-2, in NAVAIRINST 4130.1C, for a complete (detailed) list of reviews and configuration audits to be performed over the life cycle of a system. It is not suggested that Figure 4-2 contains information that should be included in a CM policy, however, the information is relevant to details for implementing CM policy and should become familiar to personnel required to implement CM under the authority of NAVAIRINST 4130.1C.

The OPR will ensure that provisions for configuration audits are included in each procurement contract, usually in the SOW [Ref. 7, par. 4.4, p. 4-1].

The authority to approve or disapprove Class I engineering change proposals, RAMECs, and major/critical deviations or waivers for PEO and NAVAIR managed items resides with the NAVAIR CCB, chaired by AIR-100. This authority may be delegated to an OPR for Class I engineering change proposals during the CE&D, DEMVAL, and EMD phases [Ref. 7, par. 5.3.2, p. 5-1].

NAWCTSD is a full time associate member of the NAVAIR CCB [Ref. 7, par. 5.13.b, p. 5-9]. The remainder of NAVAIRINST 4130.1C is concerned with details of change processes and other detailed implementing information. NAVAIRINST 4130.1C is a comprehensive document covering all aspects of CM for the NAVAIR community. The summary information presented in this subsection was gleaned to identify the salient points relevant to CM policy and implementation. The instruction is much broader in scope, however.

4. DoD Instruction 5000.2, Part 9, Section A

Because of the importance of DoDI 5000.2, the following paragraphs are quoted verbatim from the instruction. DoD Instruction 5000.2, under policies, states that an effective configuration management program shall be established to implement the decisions made in the systems engineering process by [Ref. 8, Part 9A, par. 2(a), subpar. (1),(2),(3),(4), p. 9-A-1]:

> (1) Identifying, documenting, and verifying the functional and physical characteristics of a configuration item,
>
> (2) Controlling changes to an item and its documentation,
>
> (3) Recording the configuration of actual items, and
>
> (4) Auditing the configuration item and its configuration identification.

DoDI 5000.2, also under policies, states that configuration management shall be applied to any item [Ref. 8, Part 9A, par. 2(b), subpar. (1),(2), p. 9-A-1,2]:

> (1) Developed wholly or partially with Government funds, including any Non-developmental Items (NDIs) when the

development of technical data is required to support off-the-shelf equipment or software, or

(2) Designated for configuration management for reason of integration, logistics support, or interface control.

DoD Instruction 5000.2, under procedures, describes the requirements of a configuration management program as [Ref. 8, Part 9A, par. 3(a), subpar. (1),(2),(3), p. 9-A-2]:

1. Procedures that must be tailored consistent with the complexity, criticality, quantity, size, and the intended use of the CIs. It requires the development of standard processes, and requires that these processes be used, but requires that they be tailored by means of the application of relevant military standards which are adapted to specific program characteristics.

2. Configuration management activities conducted by the Government program managers during the acquisition program. It requires that these activities, initially conducted by the program manager, transfer to the various Service systems, logistics, or material commands when the CI is transferred from the control of the program manager.

3. The processes and procedures established by mutual agreement, and documented by the lead DoD Component when more than one DoD Component is involved in the acquisition, modification, or support of the CI.

Configuration items will be directly traceable to the work breakdown structure [Ref. 8, Part 9A, par. 3.b, subpar (1), p. 9-A-2] The WBS handbook is being upgraded to include more details on the implementation of a WBS for software since this is not clearly defined in DoDI 5000.2 [Ref. 5, p. 8.9].

Configuration baselines will be used to ensure an orderly transition from one major commitment point to the next. These points are normally milestone decisions [Ref. 8, Part 9A, par. 3.c, p. 9-A-2].

Configuration changes will be controlled in accordance with MIL-STD-973. A configuration control board will be established to review proposed changes to approved configuration identification [sic] and advise the Program Manager. [Ref. 8, Part 9A, par. 3.e, p. 9-A-3]

5. MIL-STD-973

MIL-STD-973, titled "Configuration Management," contains information that is generally at a level below that considered in this thesis for CM policy. Also, many of the sections in MIL-STD-973 are covered in other sections of this chapter and are appropriately referenced. The Military Project Management Handbook referenced MIL-STD-973 frequently but once again, the references were at the implementation level vice the programmatic or policy level. Therefore, although MIL-STD-973 will be immensely important in the future for implementing CM on specific systems only one element is considered here for at the policy level as indicated in the following paragraph.

Configuration management efforts are not considered peripheral to the overall systems development effort. Contractor CM personnel must participate in (not just attend) all technical reviews conducted [Ref. 9, para. 4.2.4].

6. DoD-STD-2167A

DoD-STD-2167A, titled "Defense Systems Software," states that the contractor shall perform configuration management in compliance with the following requirements [Ref. 10, Section 4.5.2, p. 17]:

1. Establish a development configuration for each computer software configuration item CSCI.

2. Maintain current copies of the deliverable documentation and code.

3. Provide the contracting agency access to documentation and code under configuration control.

4. Control the preparation and dissemination of changes to the master copies of deliverable software and documentation that have been placed under configuration control so that they reflect only approved changes.

7. MIL-HDBK-61

MIL-HDBK-61, titled "Configuration Management," describes the life cycle related activities of CM from Concept Exploration and Development to disposition of a system. It states that there is a need to have CM purview of product development description documents as well as interface control drawings and documents. Interface documents may describe interfaces between hardware components and software components or between similar components. They may also describe interfaces between hardware and software. The important thing is that CM is presented in terms of a system and is accomplished for the life-cycle of the system. [Ref. 11, section 3.10, pp. 10-16]

The following comments are the author's comments and opinion concerning the interpretation of MIL-HDBK-61 and MIL-STD-973. These opinions were formed during six years as the Site Manager of the F/A-18 flight simulator software support activity. It is important to note what is meant by software, both in MIL-HDBK-61 and in MIL-STD-973. Configuration management of software is concerned with what is contained on the media (whatever that media is such as tape or disk) not the media itself. Configuration management of software involves management and control of the source code and the executable image produced as a result of linking and compiling source code. Configuration management of software also involves management of the documentation for that software. Documentation must verify that the binary image and the documentation are consistent and at the same level.

Software documentation can also be contained in the source code used to generate the executable image and this should also be managed as a complement to the configuration management effort. Internal source code documentation such as comments added to the source lines of code should be used to identify changes and change requirements to the code and thus comprise an element of configuration management.

This is mentioned here because many CM efforts involving software are aimed at controlling the media upon which the software is contained. Although the media must be controlled and is also a component of software configuration management, it is not the primary method of performing software configuration management. The key element is in managing and controlling the executable image and the source code that generates that image.

Of all the elements of configuration management (configuration change control, configuration identification, status accounting, and FCA/PCA audits) configuration identification can easily be argued as the most important [Ref. 11, sec. 4.1, p. 21]. All of the elements of configuration control are based on configuration identification. If a configuration is not properly identified it cannot be controlled.

Configuration identification is accomplished at three levels. They are:

1. Functional Configuration Identification (FCI). The approved functional baseline plus approved changes.

2. Allocated Configuration Identification (ACI). The approved allocated baseline plus approved changes.

3. Product Configuration Identification (PCI). The approved product baseline plus approved changes.

The composite of these three elements constitutes the physical and functional configuration identification.

8. NASA Technical Memorandum 85908

The technical memorandum is titled "Software Control and System Configuration Management: A Systems-Wide Approach." The NASA Ames Research Center developed a CM system that encompasses the whole of a system, hardware and software, in one process. The information in this section is a compendium of some of the important concepts from the NASA Technical Memorandum 85908 which is included in Appendix E. The entire document is included in the appendix, even though it is lengthy, since the concepts embodied in the approach to CM are, to this author, important for future consideration of an approach to CM from a systems concept.

The Summary to the document states:

> A comprehensive software control and system configuration management process for flight-critical digital control systems of advanced aircraft has been developed and refined to ensure efficient flight system development and safe flight operations. Because of the highly complex interactions among the hardware, software, and system elements of state-of-the-art digital flight control system designs, a systems-wide approach to configuration control and management has been used. Specific procedures are implemented to govern discrepancy reporting and reconciliation, software and hardware change control, system verification and validation testing, and formal documentation requirements. An active and knowledgeable configuration control board reviews and approves all flight system configuration modifications and revalidation tests. This report includes examples of configuration management forms and a description of the tracking process which ensures accurate and consistent records. This flexible process has proved effective during the development and flight testing of several research aircraft and remotely piloted vehicles with digital flight control systems that ranged from relatively simple to highly complex, integrated mechanizations.

The technical memorandum emphasizes the highly complex interactions among hardware, software, and system elements. The solution was to develop a "systems-wide" approach to configuration control and management. NASA's experience with the use of separate hardware and software configuration control procedures was shown to be ineffective for highly integrated systems, such as digital flight control systems. NASA purports that the use of their systems-wide approach has been very successful and is more efficient than a separate hardware and software systems approach.

The various phases of system development are described. They include definition of requirements, design, production, and ground and flight test. It is important to recognize that all of these phases are likely to require interactive development over the life-span of system and this is critical to implementing a good configuration management process.

To properly manage these phases of development, an overall system configuration management process is needed in order to provide consistent treatment of software and hardware elements. This process addresses both software and hardware elements of advanced integrated systems and accommodates the inherent iterative nature of advanced digital flight control system development. The concept of a systems-wide approach to configuration control and management (which means that the same process is used for both software and hardware system elements) is a primary contributor to the successful application of this process on a number of highly complex aircraft systems. The reader is invited to read Appendix E, NASA Tech Memo 85908, System Development Phases, p. 3 to gain more detailed information concerning this subject and related subjects in the following paragraphs.

Documentation provides a consistent and comprehensive method for documenting developmental changes. The primary goal of the documentation is to document changes implemented by all engineering disciplines involved in the project.

In the section labeled Status and Tracking, NASA states that an efficient method of tracking progress and generating status information is required for overall project management and scheduling purposes.

The reader is encouraged to read the entire NASA Technical Memorandum to gain a better perspective on the details of the systems-wide approach and its application to several projects. This sub-section was included because most of the systems acquired by NAWCTSD are similar in nature to those described in the NASA Technical Memorandum. Integrated and highly interactive hardware and software systems are common. The problems addressed by NASA are similar to problems faced by NAWCTSD in the implementation of CM across a wide variety of systems.

9. NSTS 07700, Volume IV, Book 1, Revision G

The National Space Transportation System (NSTS) 07700 (hereafter referred to simply as the NSTS document in this thesis, parts of which are included in Appendix D) provides the CM policy for the space shuttle program for both hardware and software. The space shuttle program is also called the National Space Transportation System or NSTS as in the title of the document. The following paragraphs present the major elements of CM as identified in the NSTS. The reader is invited to read Appendix D in order to obtain more details.

The NSTS defines the requirements, responsibilities, and procedures for all Space Shuttle Program (SSP) elements/projects in the application of configuration management on the SSP including applicable contractor activities.

Configuration identification determines the manner in which requirements for configuration is described. Formal documentation developed as a result of configuration identification is used to describe baselines used for planning purposes and for control and accounting of future changes. Two general types of baselines are addressed, the "NASA baseline" and the "design activity/contractor baseline." The baselines are described and reference is made to the baselines developed as the program matures from the initial baseline which consists of program management and system performance baselines. The later baselines reflect developmental items. The amount of information contained in baselines is determined on an individual basis.

At design freeze the configuration is established as verified through the development and Orbital Flight Test phases of the program. Change control is then initiated and baselines are expanded to include production drawings and the physical and functional configuration.

A NASA acceptance baseline is developed from as-built configurations of the flight hardware and software. A Space Shuttle program baseline is developed which contains program requirements, Space Shuttle management requirements, system technical requirements, descriptive documentation, indentured parts listings, and other identification documents describing the configuration of all Space Shuttle hardware and software. A list of the types of data contained in the baseline is included in Appendix D, par. 3.1.4, p. 3-3. These items comprise essential elements of the configuration baseline.

The remainder of section 3 discusses the Space Shuttle program definition and requirements baseline documentation, preparation, coordination, and processing of baseline documents, and interface control documents.

Section 4.0 discusses configuration change control. It is in this section that change classifications are defined and the use of configuration control boards (CCBs) is discussed. The use of CCBs in performing elements of CM for the Shuttle Program is essential to NASA CM policy. CCBs are responsible for approving all changes to shuttle hardware and software. There is a hierarchical system of CCBs in place to assure that both programmatic and detailed overview of changes is accomplished.

The role of configuration accounting is defined and discussed. Configuration accounting is the element of CM that provides the essential records and reporting of precise configuration data for all Space Shuttle hardware and software. The configuration accounting system maintains, stores, and correlates the accounting data including change status and information. The system produces summaries and comparisons of data as needed for individual program elements. The control of interface control drawings (ICDs) is discussed. The role of the contractor or developer is defined. The NASA system allows developers to determine which drawings and/or ICDs may be affected by a proposed change.

The Space Shuttle Program uses a data base called TDMS 2 which contains current and historical data in the form of Interface Revision Notices (IRNs). This data base allows integration of diverse elements across the spectrum of projects, developers, and Government personnel involved in the Shuttle Program. Other configuration status reports and reporting requirements are identified. Mission essential software data retention requirements are identified. The software is required to be retained for three years.

Part 6 of NSTS 07700, discusses the CM of requirements. It includes external agency requirements and interfacing requirements between program elements and projects. The need for reviews is discussed and it is stated that they will be conducted "as necessary." Reviews are also used to establish baselines.

10. Attachment 01 to Army Contract DAAH01-R-S079

This sub-section is included and Appendix F is attached to provide an example of the approach that the Army Tactical Missile System (ATACMS) project manager is taking with respect to CM on that project. The reader is invited to read Appendix F to better understand the approach the Army is taking with respect to CM on the ATACMS project.

The information presented in Appendix F would, prior to the Army's streamlining efforts in this area, have occupied many pages. The old method would have called for the application of standards and specifications. The functional specification contained in Appendix F is simple and concise. The performance specification is contained in MIS-38578 Addendum II to the contract. The reader is invited to contact the ATACMS project manager if a copy of the performance specification is desired.

The last page of Appendix F is a copy of a memorandum from the Army Acquisition Executive which addresses the delivery of contract data items. The memo requires that only one copy of each data item be delivered under a specified contract. It also states, "It is preferred and strongly encouraged that data items be delivered using electronic media."

11. IEEE Standard 828-1983 for Software CM Plans

Although this standard references plans rather than policy, the author felt that information regarding good software CM plans was important in understanding the part CM plans play in CM policy and CM policy implementation.

The application of Software Configuration Management (SCM), together with Hardware Configuration Management (HCM) and overall systems configuration management, benefits all phases of the life cycle of a system containing software components and is a matter of good engineering practice [Ref. 12, Forward].

Plans document the methods to be used for identifying software product items, controlling and implementing changes, and recording and reporting change implementation status [Ref. 12, sec. 1.1, p. 7].

Software Configuration Management Plan implementation major milestones include the establishment of [Ref. 12, sec. 3.2.4, p. 9]:

1. The configuration control board

2. Each configuration baseline

3. Schedules and procedures for SCM reviews and audits

4. Configuration management of related software development, test, and support tools

This paragraph contains information in the IEEE standard as it relates to implementing CM (or SCM) policy. Also provided in this information are examples of material which may be covered by policies, directives, and procedures and is therefore important to understand relative to overall CM policy recommendations resulting from this thesis.

Applicable policies, directives and procedures shall [Ref. 12, sec. 3.2.5, p. 9]:

1. Identify all applicable SCM policies, directives, and procedures which are to be implemented as part of this plan. The degree of implementation of each shall be stated.

2. Describe any SCM policies, directives, and procedures that are to be written and implemented for this project.

Examples of material which may be covered by policies, directives, and procedures are [Ref. 12, sec. 3.2.5(2):

1. Identification of levels of software in a hierarchical tree

2. Program and module naming conventions

3. Version level designations

4. Identification of specifications, test plans and procedures, programming manuals, and other documents

5. Media identification and file management identification

6. Document release process

7. Turnover or release of software products to a library function

8. Processing of problem reports, change requests, and change orders

9. Structure and operation of configuration control boards

10. Release and acceptance of software products

11. Operation of software library systems to include methods of preparing, storing, and updating modules

12. Auditing of SCM activities

13. Problem report, change request or change order documentation requirements describing purpose and impact of a configuration change, or both

14. Level of testing required prior to entry of software into configuration management

15. Level of quality assurance; for example verification against development standards required prior to entry into configuration management

This list includes many items applicable to both hardware and software configuration and thus constitutes a list of possible essential CM policy elements.

For each change control board and other change management bodies [Ref. 12, sec. 3.3.2.3, p. 10]:

1. Define the role of each; for example, change review authority

2. Specify their authority and responsibility

3. Identify the chairperson and the membership in the organizations, if the organizations have been formed

4. State how the chairperson and the members (and alternates) are to be appointed, if the organizations have not yet been formed

5. State the relationships of the developers and the users to the CCB(s)

The above information can be applied to hardware CM as well as software CM and thus represents candidates for essential elements of CM policy.

State the methods to be used for configuration control of interfaces with programs/projects beyond the scope of this software configuration management plan. If the software changes are required to be reviewed by other boards or teams prior to or in addition to the CCB(s), this subsection shall describe these board (or team, or both) and their relationship to the CCB(s) and to each other. [Ref. 12, sec. 3.3.2.4, p. 10]

State the control procedures for associated special software products, such as non-released software, off-the-shelf software, user furnished software, and in-house support software [Ref. 12, sec. 3.3.2.5, p. 11].

Identify, state the purposes, and describe (within the developers scope of proprietary rights) the use of the specific software tools, techniques, and methodologies to be employed to support SCM on the specific project [Ref. 12, sec. 3.4, p. 11].

B. SUMMARY OF RESPONSES

The responses to interviews conducted by the author of this thesis is summarized in this section. The interviews were conducted in an informal manner. Each person interviewed was asked what they felt were the essential elements of a CM policy and were invited to provide answers without prompting. Additional questions were asked depending upon the person interviewed and their involvement in developing CM policy. Some of those interviewed were also asked about the use of a Work Breakdown Structure (WBS) in the identification of CM items.

All interviews except those conducted at NAWCTSD itself and at the Naval Postgraduate School, were conducted over the phone. It was planned that most of the information to be derived from the comparable industry and Government sources would be derived from written literature sent to the author. Such was the case. Facts derived from written material received by the author will be summarized in the next section.

The interview with NAWCTSD personnel revealed that there was concern that CM was not uniformly implemented across the broad spectrum of devices supported. The author interviewed personnel involved in developing and maintaining the Configuration Management Information System (CMIS) at NAWCTSD. The same personnel were tasked to write the upgraded NAWCTSDINST 4130._M and will also have input to the development of the NAWCTSD CM policy statement in its final form. Other personnel interviewed were Project Directors and the Department Head and Deputy Department Head of Competency 3.0, the logistics support competency. The following paragraphs summarize their answers to questions and also provides data that was provided ad hoc to the author of this thesis during the interviews.

1. NAWCTSD MANAGEMENT

The Competency 3.0 Department Head and his Deputy had an appropriately long term, strategic outlook on the implementation of CM and the development of a good CM policy at NAWCTSD. They were also appropriately concerned with systems for the life-cycle of the system rather than just during acquisition. They discussed CM in the "out years" (years beyond the acquisition phase for Cognizance 2"0" systems) and they felt that a study would have to be done to address the issue of long term CM support. They identified the following areas of interest as potential study questions. These questions identify their concerns for CM implementation and CM policy, and also suggest study topics for this thesis and for possible future studies of a similar nature:

- What do we, NAWCTSD, want to achieve in the area of CM?
- To what level do we want CM accomplished on a given system or on the broad base of systems supported?
- What architecture should be recommended or required?
- Who are the customers for CM results, data, baselines, and information, both internal and external?
- What other organizations are successfully performing CM and what is their policy?
- What is the role of the field (ISEOs) and other competencies in the implementation of effective CM policy for NAWCTSD?
- What automated equipment should be employed in performing CM?

2. NAWCTSD CM PERSONNEL

Personnel involved in writing and implementing CM policy at the branch level at NAWCTSD were interviewed to determine their view of the challenges presented in implementing CM.

Following is a summary of their comments and concerns.

The CMIS system was developed as a local effort of NAWCTSD. It has served the purpose for which it was developed, primarily to serve as a repository for CM information in support of the TECCB, but has not kept pace with technology in the area of data base design. It is difficult to modify this data base to perform additional functions as demanded by both internal and external customers. One of the major tasks faced by personnel involved with the CMIS was to either modify it to meet new requirements or to recommend the development of an alternative Configuration Management Information System. A new system would be costly and would require time to develop and get on line. This information is provided simply to provide a more complete picture of the challenges and their priority at NAWCTSD in developing a comprehensive CM policy including the systems and personnel needed to assure that the system will function now and in the future.

On the surface, information concerning the CMIS system does not appear to be relevant to the development of CM policy for NAWCTSD. However, personnel involved in implementing that policy place the development of facilitating tools at a high priority in their work. The development of a CM policy at NAWCTSD is not dependent upon any particular type of system employed to perform the tasks to be determined, but whatever system is employed will be a factor in the success of any policy that is developed. Therefore, this information is germane to the development of policy since it is of great concern to those involved and will contribute, ultimately to the success of the policy implemented. This thesis will not attempt to recommend that any particular CMIS system be used at NAWCTSD but will assume that a satisfactory system is in place to support the goals of the resulting policy.

Other concerns of the personnel "in the trenches" was that whatever policy was developed, it had to account for the diversity of the customer data base, both internal and externaL. And, that it should be written in unambiguous terms to assure the same interpretation by all personnel involved in CM. They want the policy to clearly define responsibility and to clearly define governing instructions.

The problem of who, that is exactly which competencies within NAWCTSD, will perform what functions is important to the personnel interviewed. This is, apparently, a long term question to be resolved and one which this thesis may only partially answer.

Other concerns of the personnel interviewed were of a specific nature concerning CM as it is practiced. The concerns were at a level which this thesis will not attempt to answer and therefore, those comments are not summarized here.

3. Army TACMS (ATACMS) PROJECT MANAGER

The past ATACMS project manager was intervived. He is now a Senior Guest Lecturer at the Naval Postgraduate School. When asked what the Army CM policy was for the ATACMS system it was stated that CM was done by the contractor with Government control (chairmanship) of the Change Control Boards (CCBs). The project manager (PM) is a member of the CCB for life. This is how the Government maintains control of the system configuration. Prime contractors with sustaining funds have continuity and can thus perform CM best for the life cycle of the system.

The following paragraphs summarize ad hoc comments concerning CM and CM policy.

The weakest part of the CM effort was in performing good physical configuration audits (PCAs). The second PCA that was performed on the emergent system was done incrementally (in pieces, in a controlled fashion). This method delivered better results than the first effort.

A good CM plan is essential to the acquisition and life-cycle support of the system (of any system). The advent of the Computer-aided Acquisition and Logistics System (CALS), when fully implemented, will help improve our (Government and contractor) CM efforts.

During the interview the author was presented with and discussed the contents of several handouts. Following is a brief summary of the CM related issues discussed and contained in those handouts:

- Logistician(s) must influence the CM plan, change control process, and program funding to maintain PM-owned equipment in most current production configuration. (This equipment is frequently used to support engineering services during the production and deployment phase.)

- Logistician(s) must ensure that the CM plan imposes change control on all common-use manufacturer's tooling and Software Test Equipment (STE) and Automatic Test Equipment (ATE).

4. ATACMS Configuration Manager

Following is a summary of discussion and ad hoc comments provided during a telephone interview with the ATACMS CM manager.

CM policy for the ATACMS is different today than it was just a few months ago. The Perry Memorandum [Ref. 1] has changed the way the ATACMS program is doing business. Following is a summary of comments concerning this issue:

- No "how-tos" only "what-tos" in contractual documents.

- The Army Acquisition Executive (AAE) is adamant that PMs limit use of military standards and specifications. (See Appendix F)

- PMs are to use only functional or performance specifications not military specifications or standards. (See Appendix F for an example)

- The part of the ATACMS Statement of Work (SOW) that addressed CM used to be very specific and was contained on many pages. It is now not specific and is contained on less than one-quarter of a page. It says what we want from the contractor, not how we want the contractor to do CM. (See Appendix F)

- In the instructions to bidder, the word "plan" is out. The words "technical approach" are preferred including the contractor's technical approach to CM.

- The Government used to be carried away with format, that is not so now.

- The contractor's technical approach will include a CM technical approach.

- The ATACMS program will no longer use ECPs as a measure of performance.

- The contractor should still have the same type of information necessary to accomplish CM in the technical approach, in fact, they may still use one of the military standards such as MIL-STD-973.

The ATACMS plan is to do Physical Configuration Audits (PCAs) and Functional Configuration Audits (FCAs) as a team effort with the contractor. One of the lead team members will be the Defense Plant Representative Office (DPRO) representative who will be on the team from the beginning of the acquisition until the end.

It is important to determine the baseline while building the product instead of attempting to determine the baseline after the product is built using a PCA/FCA.

The Work Breakdown Structure (WBS) should be used to establish a configuration breakout of the system. Care should be exercised since this is a contractually controlled item and may not be the same for all programs. The level, detail, and other items may differ and may not provide adequate decomposition of the system to accommodate CM requirements.

The contractor must have drawings under a CM system.

The Government needs some type of automatic data access to the contractor's data on the project. Ultimately, the ATACMS CM manager would like to have the same exact data base that the contractor is maintaining. The Government should let the contractor know what the Government needs and have the contractor build the data base and access to the data in the data base. It could be that the Government could have automatic uploads of data from the contractor based on needs.

As companies automate and get CALS compliant, the cost of doing business should decrease. The initial cost of becoming CALS compliant should then be reduced to reflect this decreasing cost as the project progresses. The Government should leverage this to keep the initial cost of "going CALS" to a minimum.

5. Loral Corporation, Manager, Space Shuttle Project Coordination

Following is a summary of responses to questions concerning Loral's CM policy for its Shuttle Software Support Operations in Houston, TX. Appendix G contains two sections from Loral's "Space Shuttle Onboard Software Program Management and Control Process." These sections provide additional information to that provided below.

Loral has a CM policy, but it is not written as an overall CM policy for Loral. CM is totally ingrained in the entire process of software development and in everything they do in support of the Shuttle software. In fact, it is critically important to the CM effort, that the process itself be under CM, as it is at Loral.

Loral has a mature, documented software development process. It was developed with NASA's involvement and was recently rated at a Capability Maturity Model level five by a NASA team trained to perform software assessments at the

Carnegie Mellon University, Software Engineering Institute. In December of 1994, the project received an unconditional International Standards Organization (ISO) 9000 certification.

Loral does not do hardware configuration for the shuttle program. Hardware information that impacts software (extant or in development) at Loral, is passed to Loral from the CCB (NASA CCB with the hardware contractor as a member of the board).

Loral does not use an automated CM system in the development of Shuttle software. One reason is that the process was started in the 1970s before good Computer Aided Software Engineering (CASE) tools were available. Also, Loral uses HAL, a custom language developed by Loral. They also use a locally developed CM system.

6. NASA Shuttle Hardware CM Manager

Following are general comments concerning the most important elements of hardware CM as practiced by NASA on the shuttle. When asked if there was a written overall or policy statement it was stated that CM policy was a derivative of DoD policy tailored to NASA's needs. Their policy is contained in the NASA Space Transportation System 07700, Volume IV, Book 1, Revision G (see Appendix D). The following paragraphs contain information provided on an ad-hoc basis concerning essential elements of CM policy.

The project manager maintains authority over delivered hardware. This is what "drives" the system.

CCBs meet daily to control all changes.

Communication is required between shuttle hardware and software groups in order to assure that changes made to either are both known and controlled.

Most of the CM work is done by the various hardware contractors. For the shuttle space system, they maintain just one data base. The engine and tank CM data base is separate. They recommend one central data base if at all possible, with input direct from the contractor or that the contractor provide the data base and give access to the Government.

For any new undertakings, an automated CM system should be required. For older systems it is not economically viable to change from a manual system to an automated system.

7. NASA Shuttle Software CM Manager

When asked if NASA had a written or overall CM policy the reply was that the policy was contained in multiple documents that implement CM for the Shuttle. However, the document included in Appendix D is for the Shuttle Space Program and presents an overall policy. Contractors do most of the CM on the shuttle. NASA has members on or chairs multiple CCBs to control the requirements and thus the configuration of each Shuttle since each one that flies is different in many ways from the last.

Policy is also contained in multiple software and hardware management plans. The purpose, scope, definitions, and phases of software management are contained in the CM plans implemented as a result of the NSTS 07700 document (see Appendix D). Contractor CM plans are important in determining overall Shuttle CM policy. They may indeed, be the backbone of CM policy for NASA, not withstanding the NASA Technical Memorandum 85908 referenced in this thesis and the NSTS 07700 included in Appendix E which is specific to the Shuttle Program.

Hardware changes are evaluated for software impact by "smart" hardware engineers, both within NASA and by their contractors. When a hardware change impacts software the software personnel are asked to look at the change that is being proposed. If software personnel agree that a change is necessary, the information goes to a CCB for approval and scheduling. This direct information exchange system ties the hardware system to the software system and integrates the CM systems of both.

8. NPS Professors

The following information is an integration of comments received from two professors at the NPS. Both professors are members of the Information Systems Engineering and Management Group in the Systems Management Department. One teaches Software Configuration Management and has done studies for the NASA Shuttle project. The other teaches Management Information Systems and is expert in the principals of CM as practiced in industry and the Government.

One professor felt that the use of a WBS in developing a CM policy for systems is preferred mostly by high level civil servants to aid in metrics for measuring system costs and for describing the system at a high level. It can be of aid in developing a CM system but care must be used in trying to adapt it to CM use. It is used primarily for identifying costs and therefore may not be an optimum decomposition of the system for purposes of CM.

They recommended the use of automated CM tools as much as is practicable within program constraints (dollars). It would be best to use some standard in requiring an automated system, but we should not specify any particular system. The best approach is to use standard data elements to assure that all projects provide the necessary configuration management information to the level desired.

CCBs should have Government members on them or should be chaired by a Government member. A discrepancy control board should be established. Absolutely all changes to the system must be documented including requirements for the changes.

All documents, organizations, people, and requirements should be traceable from program inception to disposition of the system at the end of its useful or supportable life.

CM policy should be developed early in the program. We must determine exactly what we are trying to manage when determining the composition of a CM system. We should manage and define all interfaces in the system as well as discreet system elements. We should manage specifications (as applicable in the new acquisition environment). We should manage both hardware and software.

There must be both a functional and physical decomposition of the system.

The decision process must be identified and managed. We must also know exactly what data we need.

VI. ANALYSIS

The derivation of answers to the research questions are a product of deduction and induction and represent a whole derived from many different parts. This thesis is structured to provide answers specific to the needs of NAWCTSD with respect to an over-arching CM policy thus is broad in scope. Individual competencies within NAWCTSD may find the answers too broad to assist them in implementing the resultant policy. For those individuals, it is recommended that they study the references in this thesis with an emphasis on military and commercial standards for more specific information concerning implementation at the working level.

A. ESSENTIAL ELEMENTS OF CM POLICY

There is general agreement by the sources studied for this thesis that CM comprises four major elements. They are [Ref: 13, p. vi-vii]:

> 1. Configuration Identification. Selection of the documents which identify and define the configuration baseline characteristics of an item.
>
> 2. Configuration Control. Controlling changes to the configuration and its identification documents.
>
> 3. Configuration Status Accounting. Recording and reporting the implementation of changes to the configuration and its identification documents.
>
> 4. Configuration Audit. Checking an item for compliance with the configuration identification.

This definition is in concert with the definition provided in DoD 5000.2 and other instructions, but it is provided in terms that are clear and perhaps more easily understood. It is provided in this chapter to identify clearly the major elements of CM. The reader is invited to compare this definition with that provided in Appendix C (from NAWCTSDINST

4130._M) which includes the same elements but is in more technical terms. The definition in Appendix C also addresses digital data files. It is the same as that found in NAVAIRINST 4130.1C. The importance of the definition found in Appendix C versus that provided above is that the present policy of NAWCTSD is in consonance with technical treatises as well as the definition of CM in NAVAIRINST 4130.1C. The bottom line is that CM policy must address these four areas as well as the additional area of digital data files which is not included in the list of CM elements above.

B. CM REQUIREMENTS PER DoN, DoD, AND OTHER FEDERAL REGULATIONS

In order to discuss DoN, DoD, and other federal requirements it is important to establish which instructions are superior. For purposes of this thesis NAVAIR is the governing agency which determines CM requirements and thus CM policy for NAWCTSD. There are no conflicting instructions regarding CM policy and implementation.

The author found NAVAIRINST 4130.1C to be a comprehensive document which references SECNAVINST 4130.2 a superior instruction, hierarchically, which requires NAVAIR to establish CM policy, procedures, and guidance in processing engineering changes.

Department of Defense Instruction 5000.2 was not listed in the list of references in the cover letter to NAVAIRINST 4130.1C. It is, however, the basis for Appendix D in NAVAIRINST 4130.1C which provides information concerning CM of mission-critical computer software. DoDI 5000.2 is referenced in NAVTRASYSCENINST 4130.3 governing CM policy at NAWCTSD. Because of the importance of DoDI 5000.2 in determining acquisition policy, a part of which includes CM, that information is integrated into the following analyses.

The general policies embodied in NAVAIRINST 4130.1C will be relied upon to clearly establish the requirements for CM policy for NAWCTSD. Other elements may be determined to be required in order to define a more comprehensive policy than that required in NAVAIRINST 4130.1C. The elements contained in NAVAIRINST 4130.1C are minimum requirements for CM. Those items not covered in NAVAIRINST 4130.1C but which are included in DoDI 5000.2 and other documents studied, are discussed as appropriate in this and subsequent sections.

NAVAIRINST 4130.1C addresses requirements for the aviation community. Since NAWCTSD serves other customers outside the NAVAIR arena, other requirements may result from instructions extant at those outside agencies. Since those requirements may be dynamic and may differ from those contained in NAVAIRINST 4130.1C, it is outside the scope of this thesis to address them individually. However, the implementation of CM based upon DoDI 5000.2 and other military standards assures that other military agencies have derived CM requirements from at least some of the same documents used to derive the requirements for CM in NAVAIRINST 4130.1C. The CM policy for NAWCTSD, part of which is embodied in CM plans, may be modified as necessary to meet the needs of other agencies including those outside DoD.

NAWCTSD is designated an Office of Primary Responsibility (OPR) [Ref: 14, par. 6, p. 4]. Chapter V, page 9, of this thesis, lists the CM responsibilities for an OPR. That list of seven items represents the overall requirements of CM for an OPR and thus the minimum essential elements of CM policy for the NAWCTSD. Those requirements are not, however, inclusive of all of the elements that exist in DoN, DoD and other Federal Government regulations some of which, analysis indicates, should be included as essential elements in the resulting CM policy for NAWCTSD.

The following paragraphs will list the seven items individually and will analyze the content of each for applicability to CM policy at NAWCTSD. The seven items cover the essential elements of CM policy as identified in paragraph A. Other potential essential CM elements will be analyzed in subsequent paragraphs.

1. OPRs are responsible for providing CM of assigned CIs throughout their life-cycle. To implement this as policy it is necessary to define CM and to determine what should be the defined life-cycle. Configuration Management is defined in NAVAIRINST 4130.1C. That definition is in agreement with other definitions in technical documents concerning CM such as the "Military Project Management Handbook." Appendix C lists the definition. Also included in the definition is the definition of how CM is applied to digital data files.

The life-cycle of a system or CI is defined in DoD 5000.2. The life-cycle of systems is defined in phases beginning with the Concept Exploration and Definition phase and ending with disposition of the system at the end of the Operations and Support phase. Specific CM requirements, source documents, and baselines for individual phases are listed in Chapter V of this thesis and in NAVAIRINST 4130.1C, paragraph 1.4, p. 1-1. A comprehensive CM policy would include the information necessary to identify CM requirements during each phase of the system's (CIs) life-cycle. Other technical documents studied are in general agreement with the phases and their requirements listed in NAVAIRINST 4130.1C. Whether a system is acquired by NAWCTSD or is inducted into the NAWCTSD inventory, CM policy establish minimum CM requirements. Differences may exist based on CM systems established, or not established, in the acquisition phase of the system inducted into the NAWCTSD inventory.

All documentation analyzed indicates that CM should be started as early as possible in the acquisition phase and should be continued for the life-cycle of a system. CM should be an integral part of the development of both the software and hardware. Software is given special treatment both in NAVAIRINST 4130.1C and in the other technical documents researched. A comprehensive CM policy should state the requirements for contractors to perform CM on software in accordance with DoD-STD-2167A, Section 4.5.2, p. 17 and as listed in Chapter V of this thesis. It is important to recognize that CM on software should start early in the acquisition phase and that is why DoD-STD-2167A should be identified clearly in a comprehensive CM policy.

DoD-STD-2167A addresses CM from the contractor viewpoint and it is the contractor who will establish CM early in the acquisition phase, not the Government. It is recognized and stated in NAVAIRINST 4130.1C and in DoD-STD-2167A that standards are to be tailored as necessary to accomplish CM on a given system.

Software CM requirements must clearly establish what is to be managed with reference to source code and the executable image. This will assure that contractors approach software CM efforts with a goal that correctly mirrors the requirements of the Government. Hardware CM requirements must also establish clearly what is to be managed. Configuration identification is considered one of the most important CM requirements for both hardware and software CM. If done properly CM will be more successful since what is to managed will be clearly documented and understood by all implementers.

2. OPRs are responsible for preparing and maintaining CM plans for assigned CIs, obtaining approval of these plans, and assuring proper implementation of NAVAIRINST 4130.1C. NAVAIRINST 4130.1C requires that a CM plan be written for each CI under the cognizance of an OPR. NAWCTSD has many CIs under its cognizance and therefore an umbrella CM plan is appropriate to cover this requirement [Ref: 7, par. 2.2.2, p. 2-2].

Reference is made to IEEE Standard 828-1983 for information specific to implementing CM plans for software. Applicable policies, directives, and procedures are identified and a list is provided of examples of material which may be covered by policies, directives, and procedures [Ref: 12, section 3.2.5] It is the author's opinion that the material referenced in the IEEE Standard and in NAVAIRINST 4130.1C, as discussed in Chapter V of this thesis, form the backbone of a comprehensive CM policy for software, tailored as necessary for individual programs.

To cover individual CIs, a separate addendum may be prepared to explain and tailor policies and procedures to be followed to accomplish CM on an individual CI. If the CI is for an organization outside the DoD, it is the author's opinion that tailoring may have to be more substantial than for CIs falling under the DoD umbrella. However, this should not require an additional CM plan to be written just for those CIs. An addendum to the umbrella CM plan will suffice to tailor the plan to a specific CI outside the DoD purview. CM plans for surface and sub-surface communities of the Navy which are serviced by NAWCTSD will require less tailoring of the umbrella CM plan but most likely require some tailoring.

Overall CM policy must address situations where more than one Government agency is involved in the development, acquisition, modification, or support of a CI. This requires that a mutually approved CM plan be included as part of the program interface document. [Ref: 7, par. 1.5, p. 1-2] CM policy, in order to be comprehensive should include provisions for joint endeavors. The policy can be included in the CM policy document by reference to the appropriate section of NAVAIRINST 4130.1C.

The CM policy must also address support for systems inducted into the NAWCTSD inventory which were not acquired by NAWCTSD. Systems in this category will have to be surveyed to determine the extent of CM support developed during the acquisition phases. Systems in this category will depend upon resources available to develop or sustain CM. They will, of course, have to be supported in the same manner as other systems within the constraints introduced by available resources.

3. **OPRs are responsible for managing and providing direction for the staffing of all engineering change proposals, RAMECs, and requests for major and critical deviations and waivers from initiation until submittal to a CCB.** This requirement is thoroughly documented in NAVAIRINST 4130.1C and requires no significant analysis to implement. Questions related to this requirement are answered in the appropriate sections of Chapter V and in NAVAIRINST 4130.1C. Forms are provided in NAVAIRINST 4130.1C. Explanations for completing them and the process for routing them are clearly defined in NAVAIRINST 4130.1C, Chapter 6. Analysis of the instruction indicates that the process can be used without modification by NAWCTSD except for systems not under the purview of NAVAIR. Those systems should be adaptable to NAVAIRINST 4130.1C with minor modification to suite other agencies acting as custodians of the systems.

The CM policy for NAWCTSD should include reference to the appropriate sections of NAVAIRINST 4130.1C, contained in Chapter 6, in order to implement the appropriate change control policy.

In implementing this policy it should be remembered that AIR-100 has the authority to review and approve OPR CM plans for aviation owned CIs. In the case of non-aviation CIs, the agency owning the CI will have to review and approve CM plans for that CI.

4. **OPRs are responsible for implementing CCB directed actions.** This requirement relates to the NAVAIR CCB chaired by AIR-100 and to CCBs chartered by and thus subordinate to the NAVAIR CCB as in the case of OPRs. Class I engineering

change proposals may be delegated to an OPR during the CE&D, DEMVAL, and EMD phases. The operation of CCBs is well documented in NAVAIRINST 4130.1C and requires little analysis. With relation to implementing policy concerning CCB operation and authority, the policy for NAWCTSD can be clearly identified by referring to the appropriate section in NAVAIRINST 4130.1C.

5. OPRs are responsible for maintaining the status of implementing actions for approved engineering changes, deviations, and waivers. This requirement concerns documentation of actions approved or disapproved by a CCB. With regard to overall CM policy, NAVAIRINST 4130.1C adequately describes the process by which this requirement is accomplished. In the NAWCTSD CM policy, this can be adequately addressed by reference to the appropriate section in NAVAIRINST 4130.1C.

A good configuration control system is necessary to reduce program risk. Chapter V provided the necessary elements of a comprehensive configuration control system from DoD Directive 4245.7-M. For purposes of configuration control implementation based on an adequate policy, reference should be made to DoD Directive 4245.7-M as presented in Chapter V.

Because of NAWCTSD's extensive involvement with other Government agencies and with the surface and sub-surface communities within the Navy, the requirement for maintaining the status of implementing actions for approved engineering changes, deviations, and waivers is significant and may be more difficult to manage than it first appears. The NAVAIR policy assumes that the CI is under NAVAIR cognizance. Since this may not be the case for many CIs, under the cognizance of NAWCTSD, a clarifying statement must be included in the policy to address the interface between NAWCTSD and other agencies' CCBs. The same procedural methods, or process, can be used for maintaining the status of implementing actions. It will only be necessary to address the difference in the interfaces, data interfaces and organizational interfaces, between the agencies to facilitate information interchange.

6. **OPRs are responsible for conducting audits and establishing baselines.** The policy for conducting audits and establishing baselines should be contained in a CM policy statement. Since Government personnel will normally perform audits, CM policy should so state that fact and provide information detailing information concerning deviations from the policy. Policy should also identify the requirement that audits be performed over the life-cycle of a CI including how often they must be accomplished. CM policy must require appropriate provisions in procurement contracts to clarify Government and contractor responsibilities during all phases of the system's life-cycle.

Baseline establishment is dependent upon proper configuration identification. MIL-HDBK-61 identified configuration identification as the most important element of configuration management as identified in Chapter V of this thesis. Proper configuration identification is the key to configuration control. Thus, a comprehensive CM policy will assure that configuration identification is clearly given priority treatment in the development of CM plans and implemented CM systems.

7. **OPRs are responsible for establishing and maintaining an adequate configuration status accounting system.** One of the problems in analyzing this requirement is in determining what is meant by the word "adequate." For purposes of CM policy, the author chooses to define "adequate" as a CSA system that satisfies the data requirements of all customers both internal and external to NAWCTSD. The definition of CSA in Appendix C is more specific since it includes the elements necessary to record and report information needed to manage configuration management effectively. The policy statement

need only reference the definition of CSA, as written in Appendix C, to assure that all elements of CSA are identified as required in the resulting system.

Research indicates that a central data base is mandatory to implement this requirement. The data base should be robust enough to satisfy the needs of all users and customers both internal and external to NAWCTSD. It should also be designed to be accessible to both Government and contractor organizations in order to assure the most efficient input of data and availability of information suited to the specific needs of individual programs.

Data specifications for a central data base should be included in acquisition and internal implementing documents such as Statements of Work (SOWs) and inserted in appropriate contracts to assure data commonality among the many CIs managed by NAWCTSD. This will also assure that the system is accessible by contractor and Government agencies as needed for review and input of data.

For purposes of CM policy it is necessary to include a specific definition of the term CSA either as a reference or as an appendix to the policy. It is the experience of the author that CSA is viewed differently by every level of the implementing organizations. Implementers at the development or modification level require certain information, managers require different or summary information and so on up the chain of command. CM policy for the NAWCTSD must address the different levels of information requirements for individual users in order to establish a policy that is both adequate and effective for NAVAIR as well as other users and for those at the implementation and management stages and all users in between.

In developing and analyzing CM policy it is important to remember that tailoring is a cornerstone of present acquisition policy. Tailoring of CM requirements is also required in order to meet the requirements of multiple customers. In tailoring requirements, the limitations must be understood in order that essential or statutory requirements are not "tailored out." Authority of CCBs and other elements of CM may require waivers from NAVAIR AIR-100, in order to change them to suit a specific program.

NAVAIRINST 4130.1C should be read and thoroughly understood by all personnel and competencies required to implement CM under the policy developed by NAWCTSD. If necessary, classes should be taught to enhance general knowledge of CM requirements and implementation strategies.

One item that is not covered in the CM policy established in NAVAIRINST 4130.1C is the level to which CM is to be performed. DoDI 5000.2 states unequivocally that configuration items will be traceable to the work breakdown structure (WBS) [Ref: 8, part 9A, par. 3.b, subpar (1), p. 9-A-2]. No level is indicated in DoDI 5000.2. A work breakdown structure is required for acquisition programs which are defined in DoDI 5000.2.

Based on the requirements in DoD 5000.2, a WBS should be used to provide at least an initial system description for configuration identification purposes. This requirement belongs in a comprehensive CM policy providing the limitations of work breakdown structures are known as described in Chapter V of this thesis. Furthermore, as a matter of policy, it would be counterproductive to require that the level be greater than level three, at least in the early stages of system procurement. Levels beyond level three are developed by the contractor (the first three levels are called a WBS summary level and are developed by the program manager) and may or may not be suitable to use for a decomposition of the system for configuration identification purposes. The use of the WBS beyond level three should be determined by the specific requirements of individual programs and by available resources.

As a final note of interest in this section, it must be remembered that the Perry Memorandum [Ref. 1] is having far reaching effects on the way the Government acquires and manages systems. CM will be affected as the Government emphasizes the use of NDI and COTS and as acquisition streamlining efforts materialize. NAVAIR policy will reflect these changes as appropriate and at a time when it becomes necessary to address them. The author cannot forecast how the changes will affect CM policy in the long run. It is almost certain, however, that CM policy as it is written today will be altered to accommodate heavy contractor and industry involvement in performing CM functions. A look at the following section will indicate what is already happening on at least one other Government procurement with regard to contractor involvement in CM.

C. CM POLICIES FOR SIMILAR GOVERNMENT ORGANIZATIONS AND INDUSTRY FIRMS

1. Army Tactical Missile System (ATACMS). This program is using the contractor to perform CM functions. Government involvement is through CCB chairmanship and membership. This arrangement simplifies the resulting CM policy as is reflected in Appendix F which contains the entire contractor CM requirements in approximately one-fourth of a page. The requirements are in the form of functional requirements and thus eliminate military standards and specifications. This is in keeping with the desires of the Army Acquisition Executive.

Analysis of the CM requirements in the SOW indicate that the ATACMS program is simplifying Government responsibility in the area of CM policy and management of the CM process. The ATACMS CM manager has changed the approach to CM as practiced prior to the advent of the Perry Memorandum [Ref. 1] and in response to the Army Acquisition Executive. It is evident that the requirements for CM, from a policy perspective, are that present and future requirements for CM on the ATACMS system is entirely functionally based, contractor operated with Government CCB chairmanship, greatly simplified, and requires fewer deliverables than would previously have been required.

2. Loral Corporation. CM policy is embedded in their CM process. The emphasis on CM is that their process is itself under CM. CM is a state of mind and is prevalent in everything they do to produce the software vital to the Shuttle system. This may not be applicable directly to NAWCTSD's CM policy since NAWCTSD's policy is largely governed by higher echelon instructions. The information concerning the successful implementation of policy as practiced by Loral is excellent for study of future CM policy and for a level of contractor involvement in the CM process.

3. NASA. Both the hardware and software CM systems for the Shuttle system rely heavily on contractor involvement in the process. The only direct Government involvement in performing CM is in determining the requirements for CM in contractual documents and in chairing and performing as members of CCBs. NASA also requires that contractors maintain appropriate data bases to facilitate information requirements for both NASA and the contractor.

Research indicates that this has been a wholly successful approach to CM. The Shuttle system is one of the most complex systems in existence today. The configuration changes with each flight. Configuration management is critical to the success of the system. The system is not plagued by incompatibilities between the diverse parts of the hardware and software nor is it plagued by incompatibilities between contractor delivered material or software as indicated by the interviews conducted. This is an indication of the success of CM as practiced on the Shuttle system.

NASA's whole systems approach, included in Appendix E, is a radical change from that being employed currently. The idea of integrating the software and hardware CM process is appealing. First, it eliminates the idea of requiring two types of CM systems or processes to perform the same type of job. As stated in Chapter V of this thesis, there are many similarities in the requirements for performing CM on hardware and on software. The NASA whole systems approach recognizes the similarities and leverages them to accomplish CM in a simpler, more efficient, and ultimately more manageable CM process. The Total Quality Leadership adage is that we should concentrate on the process, not the product. That is what NASA has accomplished in its whole systems approach.

Although NASA's approach may require too much change in the present NAVAIR and NAWCTSD systems, analysis of the approach indicates that it has many attractive features and could be a subject for future theses on this topic.

D. SIGNIFICANT PROBLEMS AND ISSUES UNIQUE TO NAWCTSD

Analysis of the data indicates that the problems associated with implementing CM at NAWCTSD are exacerbated by the diverse customer base, a huge inventory of systems, and a complex interface between NAWCTSD competencies and between internal and external customers. The following paragraphs analyze those problems.

1. Organizational Problems

NAWCTSD is in the midst of a major change in its structure. Under NAVAIR guidance, the entire NAVAIR team has been designated as a Competency Aligned Organization (CAO). This thesis will not address the implementation of NAWCTSD as a CAO in any detail, it is simply noted that this change represents a major change in the "way we do business" and thus complicates the process of implementing CM policy both as it exists and with any modifications that may result from information and recommendations derived from this thesis.

In addition to the instability introduced by changing to a CAO the accomplishment of configuration management is complex and involves many different competencies and individuals. When the diverse customer base is factored in to the already complex internal interfaces required to accomplish CM it is evident that there are and will be organizational problems. Some of those problems were evident from the interviews conducted at NAWCTSD as indicated in Chapter V of this thesis and some are the result of analysis of present and potential future problems.

One of the major question concerning implementation of CM policy is determining who (which competency) is responsible for CM at NAWCTSD. There are two parts to this question. One part is who is responsible for managing CM and the other is who is responsible for implementing CM at the working level.

Competency 1.3.2 is responsible for policy and oversight as well as CCB chairmanship and CCB charters. All other competencies are implementers of CM policy. A clear cut charter for every competency involved in implementing CM at the working level must be included in any CM policy. The charter must explicitly identify the requirements of that competency with respect to CM implementation. Program level requirements such as a central data base must be addressed and managed by Competency 1.3.2.

Until recently project management may have viewed CM primarily from an acquisition perspective, not from a life-cycle perspective. Project management is now responsible for acquired systems from the concept exploration phase till disposal. This change requires that project management view the CM process as a continuum from the acquisition phase until system disposal. This means that at any given time in a program, the emphasis on CM will change depending upon the phase of the system's life-cycle. CM plans are dynamic and should be updated at each phase and thus organizational requirements should be updated at each phase to accommodate the life-cycle phase of the system. If properly addressed in the charter for every competency, with respect to individual systems, the problem of who is responsible for CM implementation at the working level should be answered. As indicated in Chapter V of this thesis, the project manager should be assisted by the assigned logistician in determining CM requirements for individual systems. This hopefully symbiotic relationship should be continued throughout the life-cycle of the system.

The responsibility of some competencies such as In-Service Engineering Offices (ISEOs) or logistics competencies will be different because of customer interface and customer requirements. Also, ISEOs actually perform engineering modifications to systems as well as support system acquisition. Most competencies will have complex interfaces with customers including both internal and external NAWCTSD customers. An overall CM plan with addenda used to tailor or modify them to specific programs will answer the question of who is responsible for implementing and who is responsible for managing CM at NAWCTSD based on which competency is responsible during a particular life-cycle phase. A CM plan is required by NAVAIRINST 4130.1C and, since NAWCTSD manages many configuration items, a master plan with addenda is both authorized by the instruction and as far as this author is concerned is mandatory for implementation of a comprehensive CM policy.

Analysis of data indicates that involvement by upper level management is necessary for any CM plan or process to work. CM as practiced in many organizations is not given a high priority by upper level management. Following is a quote concerning the involvement of upper level management in the commercial sector [Ref: 15, par. 10.1.6, p. 10-3]

> Successful major systems programs in the commercial acquisition environment are the product of unequivocal top-management approval and support. In projects reflecting the strategic emphasis of the company, there is clear linkage to organizational business strategy and a direct involvement of the CEO. Involvement does not mean micro-management, but it does mean awareness of the project's current status, an active questioning, and willingness to commit the organization's resources to resolve problems.

This commitment by upper management can be applied to Government as well as commercial organizations. In the case of NAWCTSD, project managers must be committed to CM implementation as an adjunct to their management tools as well as a life-cycle cost saving strategy.

Given a clear cut charter for all competencies involved in managing or implementing CM at NAWCTSD, an umbrella CM plan with addenda, and commitment by upper level management to the tenets of CM, the question of who is responsible for CM and who will implement CM will be answered clearly. This will eliminate many of the organizational problems extant at NAWCTSD.

2. CM Concept Interpretations

A question that has arisen frequently regarding CM policy concerns the level to which CM is to be done. It is important that this question be answered as a matter of policy because this question involves the distribution of scarce resources. Analysis indicates that as a matter of policy there can be no single answer to this question. The answer to the question was not provided by analysis of data in this thesis. Deductive reasoning provides a partial answer which may be made a matter of policy.

Department of Defense Instruction 5000.2 requires that configuration items be directly traceable to the work breakdown structure. Although the level of CM is not specified it is evident that the level is dependent upon the system's life-cycle phase. As a minimum, however, the summary WBS level should provide a good starting point for identifying the level of CM to be performed. Beyond that level, which is three levels deep, specific program requirements will determine the level to which CM is to be performed. Usually, this will be determined by the amount of resources available in a given program to support the decomposition of the system into elements that are sufficiently detailed to adequately describe the system and to facilitate CM.

The level may be different based solely on customer requirements. Once again, customer requirements will, most likely be based on available resources. The difference between resources required and resources available for CM will be no different in the determination of the CM system adapted than to any other element of acquisition or life-cycle support.

CM over the life-cycle of systems was identified in interviews as a problem for all systems. Inherent in the problem are the problems identified and analyzed in sub-sections one through three of this section. The problem of CM over the life-cycle involves who is going to perform CM, who will be in charge or manage CM, who will provide resources at a given phase of the life-cycle and what is required by instructions or regulations depending upon the life-cycle phase of the system.

The research indicated simply that CM is required for the entire life-cycle of the system. The type of CM performed during the acquisition stage is done by the development or production contractor with Government chairmanship of CCBs or at least attendance as a voting member on a given CCB. Policy should, however, clearly identify both contractor and Government involvement and responsibilities in the process. This can be done by properly maintaining the addenda to the master CM plan as the system progresses through the various phases from acquisition to operation and support.

As the system is made operable, in some cases the Government (in the case of NAWCTSD an ISEO) will perform CM exclusively, or both the Government and a support contractor will perform CM, or a support contractor will perform CM exclusively for the Government. In all of these cases a master CM plan with addenda modified and updated at each phase of the life-cycle will clarify participating roles and responsibilities.

NAWCTSD sometimes acquires a system for support after it was procured by another agency. In these cases CM for the system may have been addressed or it may accrue to NAWCTSD to develop the system. Depending on the resources available, the addenda to the master plan would accommodate starting a CM system or assuming responsibility for maintaining a CM system status-quo if it existed. CM policy must address all possibilities of required CM support as a matter of policy in order to clarify roles and responsibilities for all individuals within competencies.

3. Conflicting Regulations and Directives

This problem is addressed by determining what is required and what is recommended. Instructions are, by definition, not directives and are thus open to interpretation and some leeway in implementation. However, superior instructions carry the weight of authority of the superior organization and thus in most cases implementing organizations attempt to follow instructions as closely as possible.

In the case of NAWCTSD, the superior organization and instruction is NAVAIR and NAVAIRINST 4130.1C respectively. Measured against NAVAIRINST 4130.1C there are few if any conflicts with DoD instructions and regulations and none with existing regulations at NAWCTSD. The author was unable to find any statutory requirements with regard to CM. Therefore, it is the author's opinion that the instructions implementing both policy and CM at the working level from the Secretary of the Navy to NAWCTSD are not in conflict.

Chapter V identified the fact that NAVAIRINST 4130.1C did not indicate the level to which CM was to be performed. DoD 5000.2 requires only that configuration items be traceable to a work breakdown structure. This is not a conflict since DoD Instruction 5000.2 can be tailored to individual programs and projects. NAVAIRINST 4130.1C does not address every issue faced by NAWCTSD in implementing CM across all platforms and systems supported by NAWCTSD. This is not a conflict, it simply requires that NAWCTSD "fill in the blanks" in order to develop a comprehensive CM policy and implementation plan. In essence, latitude is allowed in order for subordinate entities to fulfill requirements that may not be known to superiors. This does not give NAWCTSD free reign to develop policy outside the legal purview of the DoD but it does give ample room to develop policy that will be successful in accomplishing the requirement to implement CM as an Office of Primary Responsibility (OPR) under NAVAIR.

The greatest single potential conflicting in interpreting and implementing CM is the interpretation and implementation of the Perry Memorandum [Ref. 1]. No other single document has such far reaching potential to cause change in the acquisition, and by default, the life-cycle support of DoD systems. For purposes of analysis by the author, it is only clear that change is inevitable. The resulting change will affect every aspect of system procurement and life-cycle support. Exactly how it will affect it and the time-table are unknown.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

NAWCTSD confronts a monumental task in responding to CM requirements across the broad spectrum of Services, other Government agencies, non-Government agencies, and a huge and diverse inventory of training devices and systems. It is clear that CM efforts at NAWCTSD can benefit by improving and clarifying policy and implementation requirements. NAWCTSD can also benefit by improving the management of its CM effort to address the differences as well as the common elements of CM across the spectrum of systems supported by NAWCTSD. Both internal and external customers will benefit if improvements are made in policy and policy implementation.

The instruction governing the implementation of CM at NAWCTSD, NAVAIRINST 4130.1C, is comprehensive and empowers NAWCTSD to accomplish its CM responsibilities in the most efficient manner possible. As an OPR, NAWCTSD is given clear directions contained in the list of OPR responsibilities. Those responsibilities are the minimum required and thus NAWCTSD may add to them as needed in order to accomplish or enhance the accomplishment of its CM mission. This thesis will recommend additional elements of CM that should be added to the list of requirements and will also suggest other changes to the present system to enhance its effectiveness.

B. RECOMMENDATIONS

To effectively implement CM policy at NAWCTSD it is necessary that upper level management commit adequate resources to accomplish and demonstrate support of CM policy. Competency 1.3.2 in its role of CM management at NAWCTSD must effectively communicate policy to all competencies tasked with implementing that policy. This thesis identifies essential elements of CM policy and addresses issues relevant to implementing that policy. The thesis did not provide a written policy. Competency 1.3.2 should modify the existing policy based on recommendations from this thesis. The resulting written policy should be concise, easy to read and easy to understand. It should reference NAVAIRINST 4130.1C as the primary superior instruction and, where appropriate for clarity, it should reference exact paragraphs or sections in that instruction in order to enhance clarity of requirements. It should also reference other DoD instructions and military standards as needed and identified in the answers to the research subsidiary questions.

The policy should identify core CM tasks to be accomplished by NAWCTSD competencies. The accomplishment of core CM tasks should be standardized with respect to data requirements and procedures. At the same time, the policy must address the CM requirements for individual programs. It must identify potential differences in implementation of CM across the spectrum of supported devices and customers and must also account for the implementation of CM by ISEOs actually performing engineering modification tasks or supporting acquisition programs.

The roles and responsibilities of every competency tasked to perform CM for NAWCTSD acquired and supported devices must be clearly established in written policy. Additionally, Competency 1.3.2 should address updating CCB charters for NAWCTSD acquired and supported devices to clarify the role of NAWCTSD versus that of NAVAIR in maintaining CCB control of baselines. In order to facilitate the diverse customer and device base, it is recommended that Competency 1.3.2 write a master configuration management plan. The policy statement should describe how the master CM plan can be modified by adding addenda to the plan as indicated in NAVAIRINST 4130.1C. The addenda can be used to tailor the master CM plan to accommodate differences in individual programs.

As chair of the TECCB and as an Associate Member of the NAVAIR CCB, Competency 1.3.2 has the responsibility to assure that all changes to existing baselines under the control of NAWCTSD are properly documented and traceable. Establishment of a comprehensive status accounting system that meets the needs of all users and customers, internal and external to NAWCTSD, must be developed. It is recommended that Competency 1.3.2 use the expertise of personnel in the Logistics Support Competency 3.0 to assist in developing CM policy, implementing CM policy, and providing life-cycle support for CM. This recommendation is based on the fact that Competency 3.0 was the lead competency until approximately November 1994. Competency 3.0 also has the lead on the development of the configuration status accounting data base.

It is recommended that the frequency of audits and the competencies responsible for performing audits be included in the written CM policy statement.

The final recommendation relative to implementing CM policy at NAWCTSD concerns training of key personnel. CM is a complex endeavor. It requires knowledge of CM processes and procedures as well as goals and limitations. The theoretical knowledge is contained in text books and articles, some of which are referenced and discussed in this thesis. The working and implementation knowledge is contained in technical manuals, instructions, and military standards and specifications. Personnel required to implement and manage CM must be trained in order to perform the necessary functions. It is recommended that Competency 1.3.2 establish a CM training plan and that specific personnel be targeted to receive CM training as needed.

C. ANSWERS TO RESEARCH AND SUBSIDIARY QUESTIONS

1. Research Question

What should be the essential elements of a Configuration Management (CM) policy for NAWCTSD acquisitions and how might this policy be implemented?

FOUR MAJOR ELEMENTS OF CM:

The question of how the policy might be implemented is answered in the subsidiary questions.

1. Configuration Identification. Selection of the documents which identify and define the configuration baseline characteristics of an item.

2. Configuration Control. Controlling changes to the configuration and its identification documents.

3. Configuration Status Accounting. Recording and reporting the implementation of changes to the configuration and its identification documents.

4. Configuration Audit. Checking an item for compliance with the configuration identification.

2. Subsidiary Questions

What are the essential elements of CM policy and what are the requirements established by DoN, DoD, and other Government agencies?

The following answers are summary answers. Detailed answers are available in previous chapters.

Essential elements include CM plans, configuration identification, change control, configuration status accounting, technical documentation management, physical and functional audits, and that CM be performed for the life-cycle of a configuration item.

NAVAIRINST 4130.1C requires the following seven CM functions (discussed in detail in the body of the thesis) of NAWCTSD because NAWCTSD is an Office of Primary Responsibility (OPR):

1. provide CM of assigned CIs throughout their life cycle;

2. prepare and maintain CM plans for assigned Cis; obtaining approval of these plans, and assuring proper implementation of NAVAIRINST 4130.1C;

3. manage and provide direction for the staffing of all engineering change proposals, RAMECs, and requests for major and critical deviations and waivers from initiation until submittal to a CCB;

4. implement CCB directed actions;

5. maintain the status of implementing actions for approved engineering changes, deviations, and waivers;

6. conduct audits, establish baselines; and

7. establish and maintain an adequate configuration status accounting system.

NAVAIRINST 4130.1C requires that NAWCTSD develop a CM master plan since it is responsible for more than one configuration item. The master plan can be tailored to suite specific programs (configuration items) by the addition of addenda to the master plan.

DoDI 5000.2 states that all configuration items be traceable to an element of a work breakdown structure. NAVAIRINST 4130.1C does not mention this requirement. It is the recommendation of this thesis that this be established as a matter of policy. Other details of requirements from DoDI 5000.2 are included in the body of the thesis.

What are the basic components of CM policies that exist for similar Government organizations and industry firms?

Research failed to identify other Government agencies that paralleled NAWCTSD in function. Other agencies do not have the same large customer base, nor are they responsible for such a large and diverse number of complex configuration items. NAWCTSD appears to be unique in that respect. Other agencies were studied, however, to determine their approach to implementing CM and their policy.

The Army Tactical Missile System (ATACMS) uses the contractor to perform CM on developing and delivered systems. Army involvement is to chair the CCB and to be a member of CCBs as necessary to assure Government control of changes. Contractual documents reflect the Army Acquisition Executives policy that functional specifications and simplified statements of work be implemented in order to streamline the process and reduce cost.

NASA uses contractors exclusively to perform CM for hardware and software. Their involvement is the same as the Army. They chair the CCBs or are members of CCBs for every element of the shuttle program.

Loral, under contract to NASA for Shuttle software development has achieved a high level of process maturity. CM is a part of every process at Loral. The process of CM itself is under CM. It is a mind set, automatically part of all processes, at every level of the company.

What are the significant problems and issues associated with establishing a CM policy that is unique to NAWCTSD and how might these problems and issues be solved?

It is important to determine exactly which competency is "in charge" of CM and which competencies are required to implement CM on their programs and systems. Competency 1.3.2 is tasked with developing and managing CM policy at NAWCTSD. Many other competencies are responsible for implementing policy. The policy developed for NAWCTSD should require that a master CM plan be written and that implementing competencies modify that plan with attached addenda to make the plan specific to their needs and to the needs of their customers.

Problems with implementation are the large customer base, the large size of the inventory, and the complex infrastructure represented by the various competencies. The

CM policy must address these issues by clarifying the roles and responsibilities of competencies required to implement CM. Acquisition documents must reflect CM requirements and provide data requirements to complement the NAWCTSD status accounting system.

Training must be developed for all personnel required to implement CM in order to assure that personnel are technically competent and to improve standardization of methodology.

The level to which CM is to be implemented is answered by the requirement contained in DoDI 5000.2 that configuration items be traceable to the work breakdown structure. It is the recommendation of this author that CM be performed to at least level three (the summary level WBS). Further system decomposition is dependent upon individual system and program requirements and resources.

CM during the acquisition phase begins at the end of concept exploration and definition. It is to be practiced on a continuum during all life-cycle phases of the system. CM plans are to be modified and updated at all major system milestones. CM on fielded systems should simply be a continuum of CM planning from the acquisition phases. If not, CM policy must dictate that necessary CM be performed in accordance with NAVAIRINST 4130.1C based on available resources and specific system requirements. For system acquired by other agencies and turned over to NAWCTSD for support under the Cognizance Symbol 2"O" umbrella, CM must be practiced the same as for all other systems within given resource constraints.

This thesis found no major conflicts between DoD, DoN, NAVAIR, and NAWCTSD instructions. Interpretation of those instructions is and likely always will be contentious. Recognition of NAVAIRINST 4130.1C as the instruction to be used to implement CM and CM policy at NAWCTSD will assure that there is no conflict. NAVAIRINST 4130.1C includes minimum instructions and therefore additional elements can be added to the policy to enhance that required by NAVAIR.

The advent of the Perry Memorandum [Ref. 1] has caused a great deal of flux in the implementation of military standards and specifications. The whole of acquisition is changing to streamline the process. CM is part of the impacted processes. MIL-STD-973 was to be the answer to standardizing CM and CM processes. The Perry Memorandum [Ref. 1] will likely affect implementation of MIL-STD-973 in a negative way.

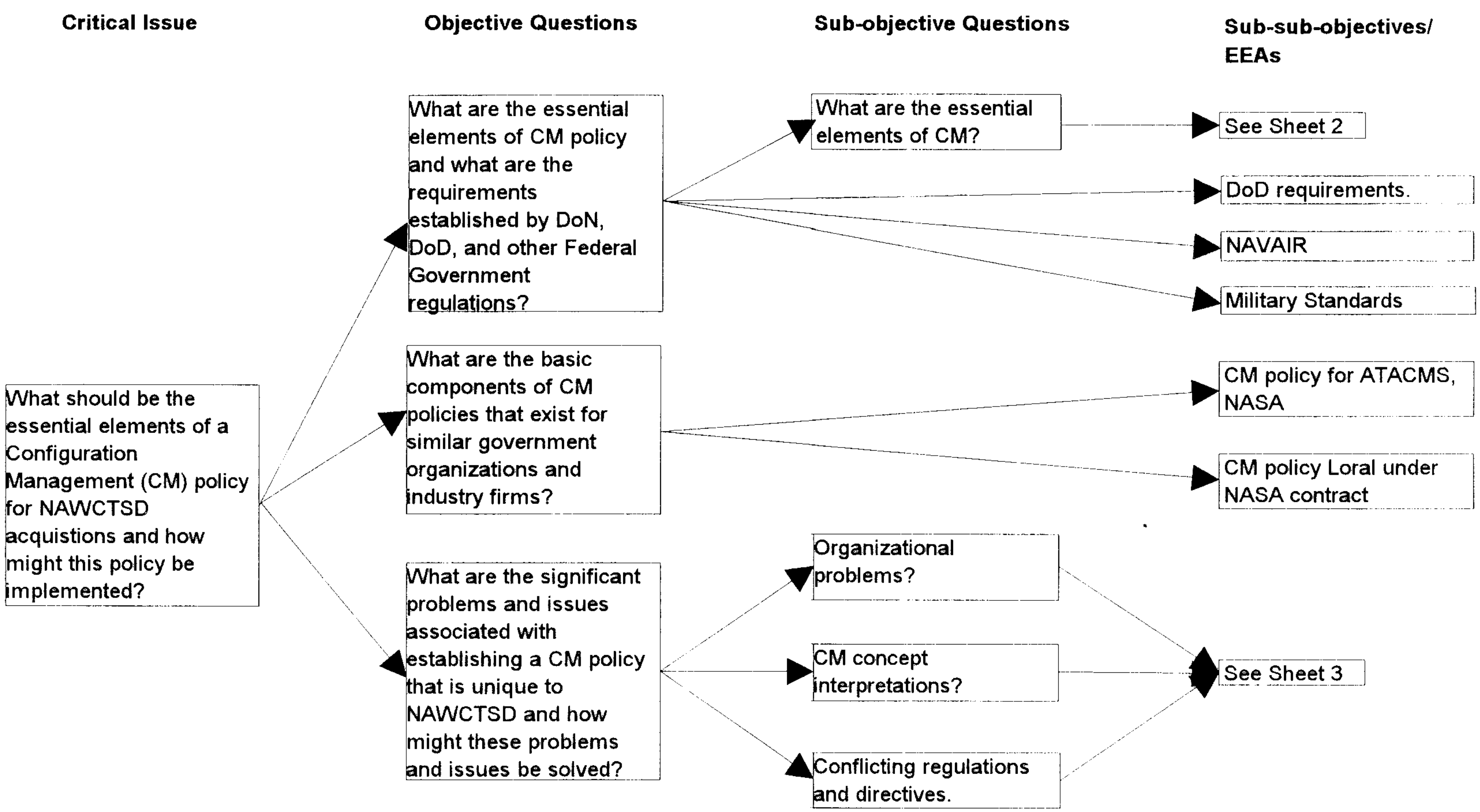
D. AREAS FOR FURTHER RESEARCH

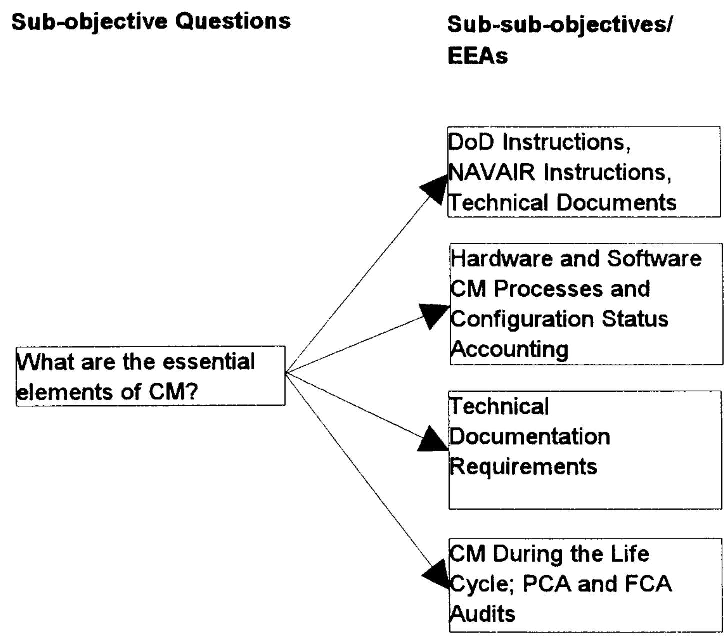
The NASA whole systems approach to CM is worthy of additional study. NASA's Ames Research Center has implemented a CM system that employs virtually the same process on both hardware and software CM.

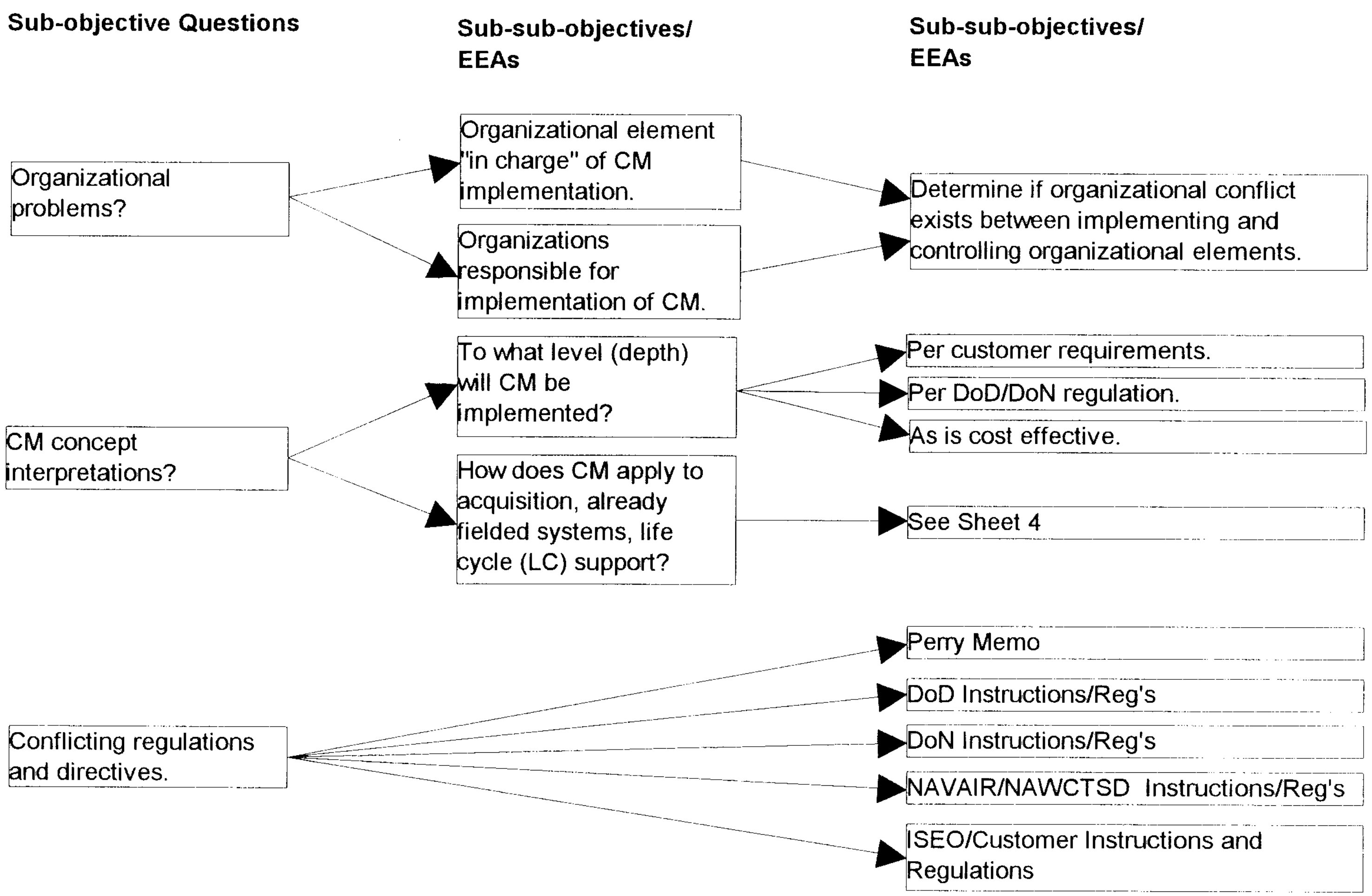
APPENDIX A

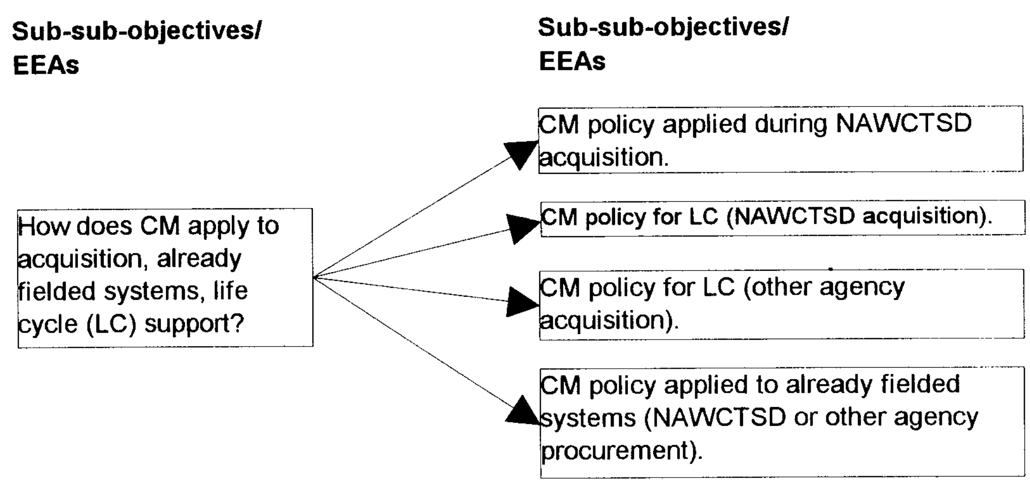
DENDRITIC ANALYSIS

Dendritic Approach to Determining Essential Elements of CM Policy for NAWCTSD




Sub-objective Questions
Sub-sub-objectives/ EEAs
What are the essential elements of CM?
DoD Instructions, NAVAIR Instructions, Technical Documents
Hardware and Software CM Processes and Configuration Status Accounting
Technical Documentation Requirements
CM During the Life Cycle; PCA and FCA Audits


Sub-objective Questions
Sub-sub-objectives/ EEAs
Sub-sub-objectives/ EEAs
Organizational problems?
Organizational element "in charge" of CM implementation.
Organizations responsible for implementation of CM.
Determine if organizational conflict exists between implementing and controlling organizational elements.
CM concept interpretations?
To what level (depth) will CM be implemented?
Per customer requirements.
Per DoD/DoN regulation.
As is cost effective.
How does CM apply to acquisition, already fielded systems, life cycle (LC) support?
See Sheet 4
Conflicting regulations and directives.
Perry Memo
DoD Instructions/Reg's
DoN Instructions/Reg's
NAVAIR/NAWCTSD Instructions/Reg's
ISEO/Customer Instructions and Regulations


Sub-sub-objectives/ EEAs
How does CM apply to acquisition, already fielded systems, life cycle (LC) support?
Sub-sub-objectives/ EEAs
CM policy applied during NAWCTSD acquisition.
CM policy for LC (NAWCTSD acquisition).
CM policy for LC (other agency acquisition).
CM policy applied to already fielded systems (NAWCTSD or other agency procurement).

APPENDIX B

GLOSSARY OF ACRONYMS

AAE	Army Acquisition Executive
ACAT I	Acquisition Category 1
ACI	Allocated Configuration Identification
ATACMS	Army Tactical Missile System
ATE	Automatic Test Equipment
CALS	Computer-aided Acquisition and Logistics Support
CASE	Computer Aided Software Engineering
CCB	Change Control Board
CDRL	Contract Deliverable
CE&D	Concept Exploration and Definition
CI	Configuration Item
CM	Configuration Management
CMIS	Configuration Management Information System
CSA	Configuration Status Accounting
DEMVAL	Demonstration and Validation
DoD	Department of Defense
DoDI	Department of Defense Instruction
DoN	Department of the Navy
DPRO	Defense Plant Representative Office
ECP	Engineering Change Proposal
EMD	Engineering and Manufacturing Development
FCI	Functional Configuration Identification
HCM	Hardware Configuration Management
ICD	Interface Control Drawing
ICWG	Interface Control Working Group
IEEE	International Electical and Electronics Engineering
ILSM	Integrated Logistics Support Manager
IRN	Interface Revision Notice

ISEO	In-Service Engineering Office (ISEO)
LCS	Life Cycle Support
MOA	Memorandum of Agreement
MOE	Measure of Effectiveness
MOP	Measure of Performance
NASA	National Aeronautics and Space Administration
NAWCTSD	Naval Air Warfare Center Training Systems Division
NDI	Nondevelopmental Item
NOR	Notice of Revision
NPS	Naval Postgraduate School
NSTS	National Space Transportation System
PCI	Physical Configuration Item
PO&M	Operation and Maintenance
O&M,N	Operation and Maintenance, Navy
OPR	Office of Primary Responsibility
PCA	Physical Configuration Audit
PD	Project Director
PJM	Project Manager
PM	Project Manager
RAMEC	Rapid Action Minor Engineering Change
RFP	Request for Proposal
SCM	Software Configuration Management
SCN	Software Change Notice
SCCB	Software Change Control Board
SOW	Statement of Work
SSP	Space Shuttle Program
STE	Software Test Equipment
SWFPAC	Surface Warfare Pacific
TECCB	Trainer Engineering Change Control Board
TECP	Trainer Engineering Change Proposal
WBS	Work Breakdown Structure

APPENDIX C

DEFINITION OF TERMS

1. ALLOCATED BASELINE. The initially approved documentation describing an item's functional and interface characterisitics that are allocated from those of a higher-level configuration item, interface requirements with interfacing configuration items, additional design constraints, and the verification required to demonstrate the achievement of those specified functional and interface characteristics.

2. BASELINE. A configuration identification document or a set of documents formally designated and fixed at a specific time during a configuration item's (CI's) life cycle. Baselines plus approved changes from those baselines, constitute the current configuration identification.

3. Cognizant Field Activity (CFA). The Navy field activity which has been assigned the responsibility and delegated the authority by NAVAIRSYSCOM HQ under reference (q) to perform all or portions of the in-service functions, including procurement support, for specific service equipment.

4. Cognizance Symbol 2"0" Equipment. Those training device end items that have been specifically developed, procured, cataloged, distributed, and supported by NAVAIRWARCENTRASYSDIV to fulfill a training requirement. It also includes training devices procured outside of the NAWCTSD and subsequently transferred by mutual agreement to NAWCTSD for inventory management, maintenance, and support.

5. Configuration. The functional and physical characteristics of existing or planned hardware, firmware, software, or a combination thereof as set forth in technical documentation and ultimately achieved in a product.

6. Configuration Baseline. Configuration documentation formally designated by the Government at a specific time during a configuration item's (CI's) life cycle. Configuration baselines, plus approved changes from those baselines, constitute the current approved configuration documentation. There are three formally designated configuration baselines in the life cycle of a configuration item, namely the functional, allocated, and product baselines.

7. Configuration Control. The systematic proposal, justification, evaluation, coordination, approval or disapproval of proposed changes, and the implementation of all approved changes in the configuration of a CI after establishment of the configuration baseline(s) for the CI.

8. Configuration Control Board (CCB). A board composed of technical and administrative representatives who recommend approval or disapproval of proposed engineering changes to a CI's current approved configuration documentation. The board also recommends approval or disapproval of proposed waivers and deviations from a CI's current approved configuration documentation.

9. Configuration Identification. Configuration identification includes the selection of CIs; the determination of the types of configuration documentation required for each CI; the issuance of numbers and other identifiers affixed to the CIs and to the technical documentation that defines the CI's configuration, including internal and external interfaces; the release of CIs and their associated configuration documentation; and the establishment of configuration baselines for CIs.

10. Configuration Item (CI). A configuration item is an aggregation of hardware or software that satisfies an end use function, and is designated by the Government for separate configuration management.

11. Configuration Management (CM).

a. As Applied to configuration items a discipline applying technical and administrative direction and surveillance over the life-cycle of items to:

(1) Identify and document the functional and physical characteristics of configuration items.

(2) Control changes to configuration items and their related documentation.

(3) Record and report information needed to manage configuration items effectively, including the status of proposed changes and implementation status of approved changes.

(4) Audit configuration items to verify conformance to specifications, drawings, interface control documents, and other tasking or contract requirements.

b. As applied to digital data files the application of selected configuration identification and configuration status accounting principles to:

(1) Uniquely identify the digital data files including versions of the files and their status (e.g. working, released, submitted, approved).

(2) Record and report information needed to manage the data files effectively, including the status of updated versions of files.

12. <u>Configuration Management Support System (CMSS)</u>. A NAWCTSD remote access computerized data file and processor utilized for configuration status accounting of changes to COG 2"0" training devices/systems.

13. <u>Configuration Status Accounting (CSA)</u>. The recording and reporting of information needed to manage configuration effectively, including:

a. A record of the approved configuration documentation and identification numbers.

b. The status of proposed changes, deviations, and waivers to the configuration.

c. The implementation status of approved changes.

d. The configuration of all units of the configuration item in the operational inventory.

14. Data. Recorded information, regardless of medium or characteristics, of any nature, including administrative, managerial, financial, and technical.

15. Design Change. See "engineering change".

16. Digital Technical Data. A primary thrust of the Computer-Aided Acquisition and Logistics Support (CALS) effort is the automation and integration of the generation, delivery, and use of weapon system technical data over the weapon system's life cycle. This technical data includes:

a. The part descriptions, product specifications, and standards that the initial designer draws upon.

b. The engineering drawings and product data used in design and manufacturing, including product descriptions and specifications data used for design reviews.

c. The information needed to guide the people who operate the system in the field, or who support and maintain it at all echelons of the logistic support structure.

d. The materials needed to train new operators, maintainers and other technicians, and the information needed for re-procurement, remanufacturing, modification, and feedback to industry for future design.

(CALS has published technical standards which enable either delivery of this information in digital form or government access to contractor-maintained technical data bases.)

17. Engineering Change. A change to the current approved configuration documentation of a configuration item at any point in the life cycle of the item.

18. Engineering Change Priorities. The priority (emergency, urgent, routine) assigned to a Class I engineering change which determines the relative speed at which the

Engineering Change Proposal is to be reviewed, evaluated, and, if approved, ordered and implemented.

19. Engineering Change Proposal (ECP). A proposed engineering change and the documentation by which the change is described, justified, and submitted to the Government for approval or disapproval.

20. Engineering Change Proposal Types. A term covering the subdivision of Class I Engineering Change Proposals on the basis of the completeness of the available information delineating and defining the engineering change. They will be identified as preliminary or formal.

21. Functional Baseline (FBL). The initially approved documentation describing a system's or item's functional, interoperability, and interface characteristics and the verification required to demonstrate the achievement of those specified characteristics.

22. Functional Characteristics. Quantitative performance parameters and design constraints, including operational and logistic parameters and their respective tolerances. Functional characteristics include all performance parameters, such as range, speed, lethality, reliability, maintainability, and safety.

23. Functional Configuration Audit (FCA). The formal examination of functional characteristics of a configuration item, prior to acceptance, to verify that the item has achieved the requirements specified in its functional and allocated configuration documentation.

24. Government Furnished Equipment (GFE)/Government Furnished Property (GFP). Property in the possession or acquired by the Government and subsequently delivered or otherwise made available to the contractor.

25. In-Service Engineer Office (ISEO). A NAVAIRWARCENTRASYSDIV field office staffed with specialists who provide Cognizance Symbol 2"0" training device/system

technical, engineering, and logistics support through direct responses to equipment users/custodians and through performance of assigned NAWCTSD device life cycle support program tasks and functions. (Reference (e) applies.)

26. Local Change Control Board (LCCB). An "on-site" modification review committee, chaired by the ISEO manager and consisting of representatives from the ISEO and users/custodians, established to exercise configuration control of trainer software on a local basis. User/custodian representation on the committee will be requested by the chairman.

27. Office of Primary Responsibility (OPR). As used in this document, includes the project manager or acquisition manager, as applicable.

28. Physical Characteristics. Quantitative and qualitative expressions of material features, such as composition, dimensions, finishes, form, fit, and their respective tolerances.

29. Physical Configuration Audit (PCA). The formal examination of the "as-built" configuration of a CI against its technical documentation to establish or verify the CI's product baseline.

30. Product Baseline (PBL). The initially approved documentation describing all of the necessary functional and physical characteristics of the configuration item and the selected functional and physical characteristics designated for production acceptance testing and tests necessary for support of the configuration item. In addition to this documentation, the product baseline of a configuration item may consist of the actual equipment and software.

31. Software. See "Computer Software" in DOD-STD-2167.

32. Specification. See MIL-STD-961.

33. Specification Change Notice (SCN). A document used to propose, transmit, and record changes to a specification.

34. System. See MIL-STD-280.

35. Tailoring. The process by which individual requirements (sections, paragraphs, or sentences) of a specification, standard, or data requirement are evaluated to determine the extent to which they are most suitable for a specific system, and the deletion of some requirements to ensure that each achieves an optimal balance between operational needs and cost.

36. TECD No. 001. TECD No. 001 is a record purpose baseline document that provides a configuration baseline summary for each new training device or system. In specific cases of major modification, the TECD Baseline Document may be assigned a number other than 001.

37. Technical Data. Technical data is recorded information (regardless of the form or method of recording) of a scientific or technical nature (including computer software documentation) relating to supplies procured by an agency. Technical data does not include computer software or financial, administrative, cost or pricing, or management data or other information incidental to contract administration.

a. Technical data is required to define and document an engineering design or product configuration (sufficient to allow duplication of the original items) and is used to support production, engineering, and logistics activities.

b. A technical data package should include all engineering drawings, associated lists, process descriptions, and other documents which define the physical geometry, material composition, performance characteristics, manufacture, assembly, and acceptance test procedures.

c. Technical data which provides instructions for the installation, operation, maintenance, training, and support of a system or equipment can be formatted into a technical manual.

(1) A technical manual normally includes operation

and maintenance instructions, parts lists or parts breakdown, and related technical information or procedures exclusive of administrative procedures.

(2) This data may be presented in any form (e.g., hard copy, audio and visual displays, magnetic tape, disks, or other electronic devices).

(3) Technical orders that meet the criteria of this definition may also be classified as technical manuals (Title 10, United States Code, Section 2302, "Definitions).

38. Technical Data Package. See "Technical Data".

39. Technical Documentation. See "Technical Data".

40. Technical Reviews. A series of system engineering activities by which the technical progress on a project is assessed relative to its technical or contractual requirements. The reviews are conducted at logical transition points in the development effort to identify and correct problems resulting from the work completed thus far before the problems can disrupt or delay the technical progress. The reviews provide a method for the contractor and Government to determine that the development of a configuration item and its documentation have met contract requirements.

41. Trainer Engineering Change Proposal (TECP). A proposed engineering change and the documentation by which a training device/system unique change is described, justified, and submitted to the Government for approval or disapproval. (Reference (d), paragraph 3.38)

42. Training Device/System. All types of maintenance and operator training hardware, devices, audio-visual training aids, equipment, systems, and related software which:

a. Are used to train maintenance and operator personnel by depicting, simulating, or portraying the operational or maintenance characteristics of an item or facility.

b. Are kept consistent in design, construction, and configuration with such items in order to provide required training capability.

43. Training Equipment Change Control Board (TECCB). The NAVAIRWARCENTRASYSDIV vehicle for coordination of COG 2"0" training device/system configuration related matters. Results of board actions represent the official NAWCTSD position regarding configuration matters. The board composition, organization, jurisdiction, and operating procedures are in Appendix D of NAWCTWDINST 4130._M.

44. Training Equipment Change Directive (TECD). A unique technical directive issued by the NAVAIRWARCENTRASYSDIV which is used to direct the accomplishment and recording of modifications to cognizance symbol 2"0" training devices/systems and companion software system items, prepared using the format in NAWCTSDINST 4130._M, Appendix J.

45. Training Equipment Change Request (TECR), NTSC 4720/2. A document which initially addresses a requirement for a configuration change to a training device/system. TECRs are normally submitted by training device/system user activities/ custodians, or by NAWCTSD ISEOs. (Reference (j) applies.)

46. Training Equipment Model Manager (TEMM). For surface trainers only, this is a NAVEDTRACOM activity, designated by the Chief of Naval Education and Training that is responsible for reviewing weapon system/platform changes for applicability and specific training systems impact assessment.

47. Validation. The process by which the preparing activity tests a technical directive for accuracy and adequacy.

48. Version. An identified and documented body of software. Modifications to a version of software (resulting in a new version) require configuration management actions by either the contractor, the Government, or both.

49. Waiver. A written authorization to accept an item,

which during manufacture, or after having been submitted for Government inspection or acceptance, is found to depart from specified requirements, but nevertheless is considered suitable for use "as is" or after repair by an approved method.

50. Weapon System/Platform Change. An Engineering Change Proposal (ECP), Ordnance Alteration (ORDALT), Ship Alteration (SHIPALT), Airframe Change (AFC), or similar change affecting an operational system or its logistic support. Such changes may or may not address training systems used in support of such operational equipment.

51. Work Breakdown Structure (WBS). See MIL-STD-881.

52. Work Breakdown Structure Element. See MIL-STD-881.

APPENDIX D

NASA CM POLICY NSTS 07700

1.0 INTRODUCTION

1.1 PURPOSE

This document defines the requirements, responsibilities, and procedures for all Space Shuttle Program elements/projects in the application of configuration management on the Space Shuttle Program.

All program level configuration management requirements for the Space Shuttle Program are contained herein. In the event of conflicting statements regarding configuration management requirements between this volume and any other SSP document, the requirement of this document shall take precedence. However, if a Program Directive has been subsequently issued by the Director, Space Shuttle Operations, which affects the statement(s) in question, the Program Directive shall take precedence.

1.2 SCOPE

This document has been jointly developed by the NASA Centers, and represents a careful application of the experience gained in previous NASA, military, and commercial space and aircraft programs. The requirements, responsibilities, and procedures defined herein are applicable to all organizations and personnel involved in the Space Shuttle program. This volume also defines those requirements, responsibilities, and procedures applicable to contractor activities necessary to achieving total program configuration management objectives.

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3.0 CONFIGURATION IDENTIFICATION

Configuration identification determines the manner in which the requirements for and configuration of all program hardware/software is described and the documentation of these descriptions. Configuration identification for the SSP shall be accomplished through the development of formal documentation, defined herein, which will describe the baseline to be used for planning purposes and for control and accounting of future changes. Refer to Appendix E for requirements and guidance in respect to Contract End Item (CEI) specifications, drawings and associated lists selection, identification and preparation. Two general types of baselines shall be addressed, i.e., "NASA baseline" and "design activity/contractor baseline." These requirements will be imposed upon the appropriate design activity/contractor by the responsible NASA project office/organization.

3.1 NASA BASELINE

3.1.1 NASA Requirements Baseline

This baseline shall be defined by the documentation that describes the current NASA approved technical and management requirements (reference Figure 3–1). The NASA requirements shall be described and controlled in program and project documentation as follows:

Area of Responsibility	Management Responsibility
Program Requirements	Director, Space Shuttle Operations, Manager, Launch Integration, KSC
Project Requirements	Project Managers

Initially, the NASA baseline consists primarily of program management and system performance requirements. As the development effort matures, the end item requirements (Orbiter, External Tank, etc.) are defined, baselined, and controlled. Each of the lower level baseline documents are compatible with the requirements of the higher level baseline documents and shall further define, as necessary, those applicable requirements. The baselines are expanded during the development effort as requirements mature. The amount of information to be contained in the baselines is determined on an individual basis.

At the appropriate time, a design freeze of the Shuttle System configurations is established to eliminate unnecessary changes and to preserve the Shuttle System configuration which was verified through the development and Orbital Flight Test phases of the program. At this time the NASA baseline is expanded to include the production drawings and a complete description of the product physical and functional configuration. Change approval authority for Class I changes (reference Paragraph 4.1) to the baseline is elevated to the SSP and selectively delegated to the Projects. Changes approved by the Projects are subsequently reviewed by the Space Shuttle Program for system implications.

The specifications for the Space Shuttle System and its elements shall consist of the documents shown in Figure 3–2.

The preceding describes a "progressive" baseline that is fundamental to the Space Shuttle Program configuration management approach. A graphical representation of this "progressive" baseline is shown in Figure 3–3.

The drawings and documents reflected in the Space Shuttle Top Assembly Drawing Tree (Figure 3–4) constitute the Space Shuttle Program baseline requirements for design and construction of the Shuttle System. These requirements shall be implemented by all affected Shuttle System design and Operation and Maintenance (O&M) activities. Implementation and change control responsibilities are defined in Appendix Q.

Program freeze points are established at specific intervals for each flight. The freeze points are defined in NSTS 07700, Volume III, Flight Definition and Requirements Directive.

3.1.2 NASA Acceptance Baseline

The as–built configuration of the flight hardware/software is documented by the accepting Space Shuttle Program/project element at the acceptance review. The NASA Space Shuttle Program control of the flight hardware/software commences with the acceptance review, and changes subsequent to acceptance (DD–250) of hardware/software will require authorization by the Space Shuttle PRCB. Configuration control of accepted flight hardware/software, including delegated authority, is defined in Paragraph 4.2 and subparagraphs.

3.1.3 (Deleted)

3.1.4 Space Shuttle Program Baseline

The SSP baseline documentation shall contain program requirements, Space Shuttle management requirements, system technical requirements, descriptive documentation, and indentured parts listings and other identification documents describing the configuration of all Space Shuttle flight hardware/software. These baseline requirements may be apportioned to the program elements/projects, by the Director, Space Shuttle Operations. The documentation shall contain the following types of data:

a. Program definition

b. Program characteristics

c. Program interface requirements

d. Program verification requirements

e. System responsibility allocations

f. System schedules

g. System budget and cost allocations

h. Management system requirements

i. Information systems requirements

j. System design and performance requirements

k. System interface requirements, excluding interfaces to be controlled by a single project office

l. System verification (acceptance, certification) requirements

m. Standard design, construction, assembly and installation requirements applicable to the total system

n. Other applicable allocated requirements

o. Training requirements

p. Acceptance baseline configuration descriptions and indentured parts listings for flight hardware/software that has had an acceptance review

3.1.5 Project Baseline

The Project baseline documentation shall contain specific requirements applicable to the particular project; e.g., Solid Rocket Booster (SRB), Orbiter/GFE, Space Shuttle Main Engine (SSME), etc. This documentation shall contain the following types of information:

a. Space Shuttle Program requirements

b. Design and performance requirements

c. Interface requirements

d. Verification requirements

e. Design, construction, assembly and installation standards and specifications

f. Training requirements

g. Design concepts, approaches, and solutions at the appropriate time

h. Product configuration descriptions at the appropriate time

3.1.6 Space Shuttle Program Definition and Requirements Baseline Documentation

The SSP baseline is included in, attached to, or referenced from NSTS 07700, Volumes I through XVIII, Space Shuttle Program Definition and Requirements. The Space Shuttle Program Definition and Requirements baseline documentation is identified for reference in the foreword to this document. The content of each volume is described in NSTS 07700, Volume I, Program Description and Requirements Baseline. All SSP documentation will be baselined and controlled in accordance with the requirements and procedures contained in this document.

3.1.7 Preparation, Coordination, and Processing of Baseline Documents

An OPR will be assigned for each SSP baseline document. The OPR will manage the preparation and coordination of the requirements to be included in its assigned volumes and, as necessary coordinate drafts up to and including a final draft of the volume to be recommended for baselining. This final draft shall be submitted for baselining via a SSP Change Request (CR). Detailed requirements and procedures for preparing, coordinating, and processing SSP baseline documents are provided in Paragraph 4.4.3 and Appendix C of this volume. Specific requirements and procedures for preparing, coordinating, and baselining SSP Interface Control Documents (ICDs) are provided in Paragraph 3.1.8 and Appendix D of this volume.

3.1.8 Interface Control Documents

ICDs shall be used to control interfaces between two or more participating contractors and government agencies. Authority for control of these documents is as follows:

a. SSP Interfaces which depict hardware/software interfaces between Projects shall be controlled by the Director, Space Shuttle Operations. Interfaces between Space Shuttle flight elements as approved by the SSP for implementation in the Shuttle Avionics Integration Laboratory (SAIL) shall be documented in addenda to corresponding flight ICDs. SAIL ICD addenda shall be controlled by the SAIL Configuration Control Panel (CCP) to the extent specified in Paragraph 4.3.3.2.1. In addition, processing of Payload ICDs which

4.0 CONFIGURATION CHANGE CONTROL

After a baseline is established, it is essential that effective, positive control be established to preclude any unauthorized changes to that baseline. There must be procedures to insure that each proposed change to the baseline is completely described (including impacts); is thoroughly coordinated, reviewed, and evaluated; and is authorized and implemented in an approved manner. Procedures also must insure that changes to a baseline are not accepted or implemented that have not been processed in this prescribed manner.

Control of the Space Shuttle requirements and acceptance baselines and changes thereto is to be through the use of Configuration Control Boards (CCBs) and the applicable baseline documentation as defined in Paragraph 3.0. The various configuration control levels for the Space Shuttle Program are depicted in Figure 4–1.

4.1 CHANGE CLASSIFICATION

All changes shall be classified as either "Class I" or "Class II". All "Class I" changes must receive NASA approval prior to implementation. "Class II" changes shall be dispositioned by the contractor's Change Control System and do not require NASA approval. The NASA shall concur on the assigned classification of each change.

After implementation of the design freeze all subsequent Shuttle System production hardware/software shall be built in accordance with the design freeze configuration baseline except for changes or waivers specifically authorized as defined herein. Proposed changes to the design freeze baseline shall be classified as Class I or Class II in accordance with the following criteria.

4.1.1 Class I Change

Changes shall be classified as Class I according to the criteria in Paragraphs 4.1.1.1 and 4.1.1.2 below. For each program element 4.1.1.1 shall apply before and 4.1.1.2 shall apply after the design freeze is established. The design freeze shall be established for the following hardware/software:

a. Orbiter – all flight and production

b. SSME – all flight and production

c. External Tank – all lightweight tanks

d. Solid Rocket Booster – all flight and production

e. Redesigned Solid Rocket Motor – all flight and production

f. (Deleted)

g. Flight Support Equipment – standard crew equipment

h. Orbiter Primary Avionics Software Version 19 and Subs

i. Orbiter Backup Flight Software Version 12 and Subs

j. KSC Launch Processing System (LPS), Checkout, Control, and Monitoring Subsystem (CCMS), and interfacing GSE software

k. Payload checkout and launch software

After the design freeze is established all changes meeting the criteria of Paragraph 4.1.1.2 shall require, as a minimum, disposition by the appropriate Project CCB. The Project CCBs are authorized to approve changes which do not affect the criteria of Paragraph 4.3.2.1 and which are:

a. Make work/make safe (required for proper fit or function or to eliminate an unacceptable safety hazard)

b. Mission unique (required to configure system for a specific mission)

c. High payback (results in significant net cost savings, performance increases, or turnaround time reductions)

d. Necessary to add a new capability to the Shuttle System to meet an approved mission requirement

4.1.1.1 Pre–Design Freeze

Before the design freeze is established for a system element, a change shall be classified as "Class I" when any of the following are affected:

a. Requirements contained in the NASA baseline

b. Contract provisions

c. Configuration of hardware/software accepted by NASA including test articles intended for major integrated tests

d. The following documentation for a particular configuration of hardware after that configuration has been certified:

   1. Engineering drawings

   2. Engineering materials and process specifications

   3. Engineering acceptance test requirements

   4. Certification/verification requirements

4.1.1.2 Post–Design Freeze

After the design freeze is established a change to flight hardware/software shall be classified as "Class I" when any of the following are affected:

a. Requirements contained in the formal NASA Space Shuttle Program or Project baseline documentation

b. Space Shuttle Program or Project schedule milestones

c. Contract cost

d. Contract provisions

e. Configuration of hardware/software accepted by NASA including test articles intended for major ground test (reference Paragraph 4.2)

f. Government furnished hardware

g. Interchangeability (as defined in Paragraph 4.4.13.5) with the design freeze configuration baseline of components or assemblies of production hardware/software not yet accepted by NASA

h. Crew procedures or training

i. Flight planning

j. Mission Control Center hardware/software

k. Qualification/certification status

l. GSE, facilities or trainers

m. Requirements and procedures defined in NSTS 08171, Operations and Maintenance Requirements and Specifications Document (OMRSD) or Operations and Maintenance Instructions (OMIs)

n. Change in procurement source of any item at any level defined by source control drawings

o. Critical process per NHB 5300.4 (1D–2)

p. Functional or performance characteristics different from that previously documented or demonstrated in actual operations

4.1.2 Class II Change

Any change which does not fall within the Class I definition shall be designated as Class II.

4.2 CONFIGURATION CONTROL OF ACCEPTED FLIGHT HARDWARE/SOFTWARE

To facilitate synchronization of the Space Shuttle System configuration among the various program elements/projects and to assure a coordinated, timely reaction of all program elements/projects to necessary changes to the configuration of flight hardware/software after NASA acceptance (DD–250), all configuration changes and requests for performance of non–standard work will require authorization by the Space Shuttle Program or, where applicable, the delegated project. This authorization will be obtained prior to issuance of work authorization at the using site. The mechanisms for dispositioning these changes are the Space Shuttle PRCB, Special Daily Space Shuttle PRCB (reference Paragraph 4.4.13.6), or the appropriate Project CCB. Changes that do not meet the criteria of Paragraph 4.4.13.6, such as drawing corrections, clarifications, addition of true alternate parts, and non–mandatory flow enhancement changes (which relax assembly requirements but meet SSP requirements) can be dispositioned by the Project CCB. Emergency changes to accepted flight hardware/software may be implemented in accordance with Paragraph 4.4.3.2.1.

Configuration changes which violate any of the SSP criteria defined below (a – g) must be forwarded to the Space Shuttle Program for disposition. Other configuration change approvals are delegated to the projects as defined in Paragraphs 4.2.1, 4.2.2, 4.2.3 and 4.2.4.

a. Impact performance, safety, resources or major milestone schedules.

b. Affect SSP interface control document requirements.

c. Cannibalization of flight hardware.

d. Changes associated with resolution of major anomalies or incidents, or changes which are deemed significant to the program.

e. Engineering or hardware required to incorporate the change will not meet the specified site need date.

f. A flight hardware change that impacts any level of assembly interchangeability (Paragraph 4.4.13.5).

g. Impacts other projects (except as delegated in Paragraphs 4.2.1 and 4.2.4) or program elements, i.e., mission operations, flight crew operations, flight software, Launch Commit Criteria (LCC), etc.

Requests for non–standard work performed at the launch site which violate the criteria defined in Paragraph 4.4.13.7a, must be forwarded to the Space Shuttle Program for disposition.

5.0 CONFIGURATION ACCOUNTING

Configuration accounting is the element of Configuration Management (CM) that provides the essential records and reporting of precise configuration data for all Space Shuttle hardware/software. The primary objectives of configuration accounting are as follows:

a. To maintain and disseminate the current configuration data of each program/project element

b. To maintain correlation among the configuration data for various equipment, software, and support elements

c. To maintain current and accurate records of the status of changes completed and in process

The configuration accounting system shall include the task of maintaining, storing, and correlating configuration documentation of all hardware/software. This includes activities required to receive inputs from the design activity release desk (as–designed), quality control (as–built), and other sources (i.e., as–tested, as–qualified, as–delivered, as–flown, etc.); and to compare, summarize, and produce configuration summaries, differences, and other comparison data as may be of value to various program organizations.

5.1 ICD CROSS–REFERENCE SYSTEM

Each design activity/contractor shall maintain a system that indicates which engineering drawings are affected by Space Shuttle Program and project ICDs. This system will allow the designer or other affected parties to determine which drawings and/or ICDs may be affected by a proposed change.

5.2 SPACE SHUTTLE INTEGRATED PROGRAM ICD STATUS

The Space Shuttle Program shall utilize the NASA Open IRN Report and the Historical IRN Report which reside in the TDMS 2 data base. Current and historical data, including latest ICD revision and IRN incorporation are available on–line in TDMS 2.

The Space Shuttle Program shall utilize the payload Preliminary Interface Revision Notice (PIRN)/IRN Report which resides in the Automated Mission and Payload Tracking System (AMPTS) for current payload ICD information.

5.3 PROGRAM DOCUMENT DESCRIPTION AND STATUS REPORT

The Space Shuttle Program shall utilize NSTS 08102, Program Document Description and Status Report, which is a listing of current revisions and changes to all SSP baseline documents. This report will be used to identify the status of the NASA baseline documentation. Applicable projects, design activities and contractors shall be furnished NSTS 08102 to review and, if necessary, to redline changes to the document. NSTS 08102 shall be maintained by the Space Shuttle Management Integration Office.

5.4 CONFIGURATION STATUS REPORTING

Configuration accounting and verification functions shall maintain or have access to complete and accurate records on the location and configuration status of all Contractor Furnished Equipment (CFE), GFE, and commonality items of equipment. The records will include such data as nomenclature, manufacturer's identification, required and scheduled delivery dates for modification kits, planned and actual usage of each serial number, and additional notes as required.

Records will be monitored by each project on the status of changes being managed by the project. These records will enable an audit trail to be accomplished, from acceptance of each CR through verification of change implementation. The records will include a cross–reference to the following, where required:

a. CRs

b. Change proposals

c. NASA Configuration Control Board Directives (CCBDs)

d. Baseline documentation status

e. ICD status

f. Technical directives

g. Contract Change Authorization (CCA) (if applicable)

h. Retrofit/Modification kits

Status accounting reports will be used to support acceptance and delivery of hardware/software as well as reviews and inspections.

The foregoing elements of data (as a minimum) shall be maintained by the design activity/contractor and shall be a product of the configuration accounting system. Appropriate summaries, evaluations, and status reports will be prepared from this data for submittal to the NASA as required.

5.5 MISSION EQUIPMENT CONFIGURATION ACCOUNTING

Mission equipment installation requirements for each Space Shuttle flight are specified in the MECSLSI drawing and the CCCD for that flight. The configuration accounting system which shall be used to track mission equipment assets, status compliance with the MECSLSI and CCCD drawing requirements and provide associated reports is defined in Appendix R.

5.6 MISSION–ESSENTIAL SOFTWARE DATA RETENTION

Mission–essential software elements (GPC, SSME, LPS and Mission Control Center [MCC]) shall retain "as flown" software configurations (executable code, mission–unique data, and related documentation) for a minimum of three years. Refer to NSTS 07700, Volume XVIII, Book 3, Computer Systems and Software Requirements, Software Management and Control, for further details.

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6.0 CONFIGURATION VERIFICATION

Configuration management includes activities associated with assuring that requirements are properly implemented and hardware/software is certified as having been designed and built to the correct configuration. This effort shall be an intrinsic part of the overall management approach on the program.

6.1 SSP REQUIREMENTS VERIFICATION

The Space Shuttle Program, having authority for the development and control of the NASA baseline, shall ensure that all external agency requirements and interfacing requirements between program elements/projects have been properly incorporated into the baseline. Requirements, design, and hardware/software configuration reviews will be conducted as necessary to ensure that this is accomplished. These reviews also will be used to establish baselines for further development of requirements and to validate the approaches taken to the solution to these requirements. The reviews considered to be SSP requirements are defined in the following subparagraphs.

6.1.1 Program Requirements Review (PRR)

This review encompasses all major SSP participants and is chaired by the Director, Space Shuttle Operations, or delegated representative. The purpose of the review is to review and update program requirements and evaluate the management techniques, procedures, agreements, etc., to be utilized by all participants. This review evaluates CM procedures and formats required to satisfy the program requirements.

6.1.2 Shuttle System Requirements Review (SRR)

This review encompasses all major SSP participants and is chaired by the Director, Space Shuttle Operations, or delegated representative. The purpose of this review is to update the program and system requirements to be utilized by the contractors for the SSP. These requirements are documented as the NASA SSP baseline (reference Paragraph 3.1.4), implemented with the contractors, and placed under configuration change control.

In addition to the system requirements, other program element requirements may be reviewed and evaluated to ensure they conform to the system requirements and that contractors have correctly interpreted the NASA requirements for the program elements.

Prior to or at the SRR, ICD responsibilities will be defined and documented and master schedules for ICD completion will be established.

6.1.3 Preliminary Design Reviews (PDRs)

Preliminary Design Reviews will be conducted by each responsible NASA Project office with their NASA in–house design activity/contractor, prior to, or very early in the detail design phase. The PDR is a technical review of the basic design approach for configuration items and for selected major changes to these items to assure compatibility with the SSP and Project requirements (including interface requirements) and the producibility of the design approach. Cost and schedule relationships also will be reviewed. This review will update the Project requirements to be utilized by the NASA in–house design activities/contractors for the applicable Project. These requirements, including those contained in the Statement of Work/Requirements, shall be documented as the NASA Project baseline, implemented with the NASA in–house design activity/contractor, and placed under configuration change control. In the event Project requirements have been baselined prior to PDR, they will be updated as required to incorporate the applicable results of the PDR.

All ICDs applicable to a PDR should be baselined to reflect appropriate interface requirements prior to PDR completion. When any PDR is completed, all applicable ICDs must be baselined and implemented with the affected contractors and placed under configuration change control.

Typically, the items for review at the PDR should include the following:

a. Preliminary ICDs

b. Design analyses

c. Layout, general arrangement, and envelope drawings

d. Schematics and block diagrams

e. Sizing, trade study, and design study results

f. Material and process specification listings

g. Applicable procurement specifications

h. Test requirements

i. Mockups and models

j. Updated plans, procedures, and schedules

k. Commonality candidates; identification, rationale, and status

l. Proposed additions to the NASA baseline

m. Selected SR&QA documentation (FMEAs, CILs, hazard analyses, etc.)

The PDR should result in the authorization to the contractor to proceed with further design in accordance with the reviewed design approach, interface requirements, commonality items, etc., and approval or update of the project baseline documentation.

APPENDIX E

NASA TECHNICAL MEMORANDUM 85908

NASA Technical Memorandum 85908

Software Control and System Configuration Management: A Systems-Wide Approach

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1984

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SUMMARY

A comprehensive software control and system configuration management process for flight-critical digital control systems of advanced aircraft has been developed and refined to ensure efficient flight system development and safe flight operations. Because of the highly complex interactions among the hardware, software, and system elements of state-of-the-art digital flight control system designs, a systems-wide approach to configuration control and management has been used. Specific procedures are implemented to govern discrepancy reporting and reconciliation, software and hardware change control, system verification and validation testing, and formal documentation requirements. An active and knowledgeable configuration control board reviews and approves all flight system configuration modifications and revalidation tests. This report includes examples of configuration management forms and a description of the tracking process which ensures accurate and consistent records. This flexible process has proved effective during the development and flight testing of several research aircraft and remotely piloted research vehicles with digital flight control systems that ranged from relatively simple to highly complex, integrated mechanizations.

INTRODUCTION

The complex and integrated nature of the flight-critical digital control systems of advanced aircraft necessitates a rigorous software control and system configuration management process to ensure efficient flight system development and safe flight operations. Over the past 10 years, the Dryden Flight Research Facility of NASA Ames Research Center has developed and refined a comprehensive configuration management process, which has been applied to several research aircraft and remotely piloted research vehicles with digital flight control systems that ranged from relatively simple to complex and highly integrated mechanizations. This flexible process has proved effective for the F-8 digital fly-by-wire (DFBW) and the highly integrated advanced fighter technology integration (AFTI) F-16 research aircraft, as well as the 3/8-scale F-15 spin research vehicle (SRV), the highly maneuverable aircraft technology (HiMAT), and the drones for aerostructural testing (DAST) remotely piloted research vehicles.

Various methods and approaches for software control and system configuration management have been used successfully, and many have been published in the literature. All systems have some unique and dominant characteristics; advanced aircraft flight control systems are no exception. Because of the highly complex interactions among the hardware, software, and system elements of a state-of-the-art digital flight control system design, a systems-wide configuration control and management process is necessary. Experience with the development of various advanced flight systems has shown that use of separate hardware and software configuration control procedures is ineffective for highly integrated flight systems in that many of the difficult design, development, and testing issues involve interactions between hardware and software systems.

This paper describes the process and procedures of a highly successful and efficient software control and system configuration management technique for advanced aircraft digital flight control systems. Experience with several advanced vehicle systems is described, and specific examples are given to illustrate the implementation process.

NOMENCLATURE

AFTI	advanced fighter technology integration
CCR	configuration change request
DAST	drones for aerostructural testing
DFBW	digital fly-by-wire
DR	discrepancy report
HiMAT	highly maneuverable aircraft technology
PC	program change
RAV	remotely augmented vehicle
SRV	spin research vehicle
STR	system test report
WO	work order

SYSTEM DEVELOPMENT PHASES

The proper application of a successful software control and system configuration management process requires a thorough understanding of the various phases required for development of an advanced system. The primary phases for development of an integrated digital flight control system for an advanced aircraft are definition of requirements, design, production, and ground and flight test (fig. 1). Recognizing that all these phases are likely to require interactive development over the lifespan of a complex system is critical in the implementation of a configuration management process.

The definition of requirements typically begins with specification of the broad mission requirements and culminates with a conceptual design of the system. The conceptual design is presented in a comprehensive system specification document which describes the overall system characteristics, including the functional requirements of the hardware and software. Other requirements defined in this phase include the equipment and facilities required for system testing, the staffing plan, and the documentation procedures.

The generation of detailed specification documents outlining specific system hardware and software requirements is an initial step of the design phase. These documents must satisfy the requirements of the comprehensive system specification document. During the design phase, the overall plan for software control and system configuration management is defined, and specific procedures and responsibilities are established. A series of specification and design reviews is essential for the efficient evolution of the system development.

After the critical design review is the software and hardware production phase, which requires the mechanization of various tools and facilities. Generally, the hardware and software elements of a complex system are initially tested independently using specialized stand-alone equipment and facilities. After functional verification tests, the software and hardware elements are integrated for final ground testing, overall system validation, and flight qualification tests. A flight readiness review is conducted prior to flight test evaluations to assess the results of the various ground tests and the flight readiness of the vehicle and flight systems.

To properly manage these phases of development, an overall software control and system configuration management process is needed to provide consistent treatment of software and hardware elements. This process is designed to include both the software and hardware elements of advanced integrated systems and accommodates the inherent iterative nature of advanced digital flight control system development. The concept of a systems-wide approach to configuration control and management (which means that the same process is used for both software and hardware system elements) is a primary contributor to the successful application of this process on a number of highly complex aircraft systems.

PROCESS DESCRIPTION

The primary purpose of the software control and system configuration management process for flight-critical digital flight control systems is to provide a method for efficient flight system development and a procedure for assuring safe flight operations. The process is designed to control system configuration changes by managing the primary system development phases described previously, and to resolve discrepancies uncovered during system testing. In addition, the configuration control process prescribes stringent test and documentation requirements and provides for visibility of changes across all involved engineering disciplines through formal review procedures.

The overall software control and systems configuration management process (fig. 2) can be divided into four phases, analogous to those of the system development process. Requirements for configuration changes arise from new software or hardware system requirements or from discrepancies noted during system analysis or test. An important element of this change-in-requirements phase is the documenting and reporting of system discrepancies. All system development personnel are responsible for documenting and reporting all discrepancies, software or otherwise, found during system operation and test. A standardized form for discrepancy reporting aids the documentation and tracking process. When the discrepancy is discovered, the anomalous behavior and the system software and hardware test configuration are documented in detail. The cause of the discrepancy and the required fix are usually determined at a later time; a method of working around the problem or a temporary fix may be incorporated if necessary to continue testing.

After the change requirements are defined, analyses are undertaken to define and then design the required software or hardware modifications. For changes required as a result of a system discrepancy, the cause and required fix are indicated on the discrepancy report form. A configuration change request form is prepared for any change required. Before being implemented, each system hardware or software change must be reviewed and approved by the configuration control board which includes software, hardware, systems, operations, and management personnel. This board provides the forum for disciplinary and flight test engineers to discuss the changes and their impacts, identify test or retest requirements, and determine the effects of the changes on operational procedures or system performance. The configuration control board approves, returns for further analysis, or rejects the specific hardware and software changes requested and then formally documents the action taken. If a system hardware modification is required, a work order form is prepared to provide a detailed description of the modification. If a system software modification is required, a program change notice is prepared to describe the specific change and the reason for and impact of the change.

The primary function of the software control and system configuration management process during the production phase is to assure that proper procedures are followed in the implementation of the approved changes and that requirements for updated documentation are met. A hardware drawing is updated, and after fabrication, the modification is inspected for quality assurance and compliance with the work order. The software manufacturing process is highly dependent on the specific computer equipment and software development tools and varies greatly from system to system. An important element common to all software production processes is the requirement for adherence to formal written procedures detailing specific sequences in the manufacturing process as well as for updating the formal software documentation.

The configuration management process has an integral function in the testing that follows the incorporation of any change. Procedures that govern verification and validation test requirements are implemented for both software and hardware modifications. Written system verification and validation test reports are required for all system elements and for all system changes. The verification test for a hardware change includes the visual inspection and continuity check which determines that a hardware item is constructed and wired in accordance with the drawing. Hardware validation involves a series of systems functional tests which are performed to qualify the design and its implementation. Software verification is the testing process that formally assures that the software is coded in accordance with its design specification. The software validation step assures that the specified software change accomplishes the desired objective within acceptable limits and operates correctly in the operating environment of the total system. The system validation testing often uncovers system discrepancies resulting from the integration of the hardware and software. Adherence to an established written policy concerning software reverification and system revalidation testing after a software change is required. The documented test results are reviewed by the configuration control board for adequacy and completeness before the modified hardware or software is released for pre-flight checks and flight testing of the system.

The configuration control board plays a vital role in a successful software control and system configuration management process. The board assures that a coordinated closed-loop process exists at all system development stages by controlling system configuration changes arising from new requirements or discrepancy reconciliations and by reviewing implementation details and test results. An active and knowledgeable configuration control board greatly enhances the efficiency of complex and integrated system developments by maintaining the essential common thread of knowledge and experience.

Documentation

An essential part of the software control and system configuration management process is a comprehensive and consistent method for documenting developmental changes. The primary goal of this documentation is to provide communication and therefore visibility of changes across all involved engineering disciplines. The documentation generated during the validation and test phases of the system development process provides the means by which conformance to the overall mission requirements is tracked and controlled. The material generated for the various design and readiness reviews is also a valuable documentation element.

A method for "checks and balances" is provided on the forms used for system configuration control documentation and tracking (fig. 3). Closing the loop on the change control process is essential in the development of a complex flight system. To assure that changes are tracked, tested, and documented properly, the discrepancy report, configuration change request, program change, work order, and system test report forms are cross-referenced. Each form has a unique identification number to aid this cross-referencing process. Examples of the forms used are included in the appendix.

The closing action section on the discrepancy report form provides space for recording the configuration change request, program change, and work order numbers identifying the implemented change. The configuration change request form cross-references all the other forms and is the primary form used for assuring that the change has been implemented and documented properly. The program change form used for software changes references the discrepancy report and configuration change request numbers. In addition, specific software release identification and documentation updates are referenced on this form. The work order form includes a reference to the discrepancy report if the change is the result of a system discrepancy and also provides for documentation of the quality assurance inspection. Hardware drawing updates are generally attached to the work order form. The system test report forms are used for documenting all formal system testing and the retesting required after system changes. For tests resulting from the implementation of system changes, the program change or work order number is referenced.

Status and Tracking

An advanced flight system development program commonly has a large number of discrepancies, changes, and tests in various stages of resolution, design or analysis, and accomplishment, respectively. An efficient method of tracking progress and generating status information is required for overall project management and scheduling purposes. Manual recordkeeping and documentation control may be adequate for simpler system development projects, but becomes cumbersome and ineffective on larger, more complex projects.

An automated method for maintaining tracking and status information for complex flight system configuration modifications has been developed using a microprocessor-based computer system. Standard data-base management software is used to create files containing all pertinent information required to track system configuration status. The computer system is used to store, update, and retrieve information pertaining to the status of discrepancy reports, configuration change requests, program changes, work orders, and system verification/validation test reports. Hardware and software documentation updates are also tracked. Various sorting and indexing methods are used to generate hard-copy status reports in a variety of formats. This automated system has proved to be an accurate and efficient tool in the overall software control and system configuration management process.

APPLICATION EXPERIENCE

The process for software control and system configuration management has been applied to several research aircraft and remotely piloted research vehicle programs, including the F-8 DFBW, AFTI/F-16, HiMAT, F-15 SRV, and DAST. All these vehicles have integrated digital flight control systems; the mechanization complexity varies greatly. The key elements of the process were adapted for specific application on each of these programs, demonstrating the flexibility of the overall concept. The point at which the formal configuration control process begins varies from program to program but generally starts when the baseline system configuration has matured to the point of allowing efficient formal testing without undue restrictions or operational difficulties. The software control and system configuration management methods described in the previous section represent the current status of a continually evolving process; experiences from each program contribute refinements and enhance both the overall approach and specific procedures. The process, as detailed in figure 2, is certainly not envisioned to be directly applicable for all programs; however, it has provided a basic framework from which useful configuration control and management procedures have been developed.

The configuration control process used on the highly complex AFTI/F-16 aircraft was largely based on these concepts. Over 100 flights were accomplished and 13 major software releases were developed and qualified for the AFTI/F-16 digital flight control systems during the first year of flight testing. More than 330 discrepancy reports were processed during the development and flight test activity, and over 95 software program changes were implemented. Specific details of the configuration control process used on the AFTI/F-16 aircraft program are contained in reference 1. The following sections outline application experience on the F-8 DFBW and HiMAT research programs; the experiences with the F-15 SRV and DAST programs were similar.

F-8 DFBW Program

The F-8 DFBW research aircraft was first flown in 1972 with a simplex, full-authority digital flight control system using ultrareliable system hardware from the Apollo spacecraft program and a triply-redundant analog backup system. The first flight of the second phase of the F-8 DFBW program, which occurred in 1976, used a triply redundant, full-authority digital flight control system for primary control and a triplex analog backup system. The flight qualification and validation experience gained on the F-8 DFBW flight program is described in reference 2. The commitment to remove the aircraft's mechanical control system before the initial flight test forced the development of a comprehensive set of qualification procedures, including a process for software control and system configuration management. This early process, which stressed rigorous testing procedures and formal documentation, provided the basis for the current process.

The triply redundant primary flight control system of the F-8 DFBW was designed as a flexible research testbed, and has allowed many flight control and system research experiments to be investigated in flight. In over 6 years of active flight testing and nearly 150 flights, a total of 40 software releases have been qualified and used in ground and flight tests. The software control and system configuration management system has been used successfully to track over 500 discrepancy reports and to process more than 320 program changes to the onboard flight-critical software.

The F-8 DFBW aircraft also has the capability to use a remotely augmented vehicle (RAV) flight test technique for investigating advanced control law concepts in a cost-effective manner. The RAV concept (ref. 3) uses a ground-based, FORTRAN-programmable digital computer for control law computations and up and down telemetry links to allow complete closed-loop control. The technique was designed to provide the flexibility and versatility necessary to investigate advanced or highly speculative control concepts in flight. The onboard flight software treats the simplex RAV interface and mechanization as another flight control mode and contains the necessary validity checks required to maintain overall system integrity.

The RAV ground computer system and software configurations were developed and managed using the same process as was used for the onboard software and flight systems. The system testing approach was modified slightly to account for the less critical nature of the RAV ground systems and software. The systems-wide approach to software control and systems configuration management made the accommodation of the additional RAV software and system hardware elements a relatively easy task. The process thus demonstrated its inherent flexibility to accommodate and manage complex system hardware and software elements that might be added to an advanced aircraft flight system after the initial development phase.

HiMAT Program

The HiMAT program was conceived to demonstrate advanced technology concepts through flight tests of scaled aircraft using a remote piloting technique. Advanced composite structures, aeroelastic tailoring, a digital integrated propulsion control system, reduced static stability, and a microprocessor-based digital fly-by-wire control system are all elements of the HiMAT program. Closed-loop primary flight control is performed from a ground-based cockpit, using a digital computer and up and down telemetry links. A backup flight control system for emergency operation resides in an onboard computer. The onboard systems, which are designed to provide fail-safe or better capabilities, use two microcomputers, dual uplink receiver/decoders, and redundant hydraulic actuation and power systems.

The HiMAT system development and flight qualification was a complex, highly integrated task (ref. 4). Four independent flight-control digital computers, all with different software programs, were required to meet the research program objectives. The two ground-based computers were programmed in FORTRAN, and the two onboard computers were programmed in assembly language. The software development facilities, verification tools, and ground support equipment used for system validation testing were specific to each computer system. The various computer hardware and software elements were quite diverse, yet the overall flight system functions were highly integrated. A coordinated and consistent software and system development process was essential in the qualification and flight test activities.

In over 4 years of development and ground and flight test activities, 30 software releases were generated for the 2 onboard computers, 24 software releases for the primary ground computer, and 11 software releases for the other ground computer. Nearly 500 discrepancy reports were written and resolved, over 320 work orders were processed for flight system hardware modifications, and over 480 program changes were incorporated in the various software elements. In general, the HiMAT program used the outlined discrepancy reporting, software change, and system verification/validation test procedures quite rigorously. However, the system hardware modification process was tailored to respond to the many unique and dynamic requirements of the HiMAT flight system development. In particular, many of the system hardware changes did not require the review and approval of the configuration control board; the cognizant systems engineer authorized the modifications directly. Any major flight control system hardware modifications and those of an integrated-systems nature were processed according to the established procedures for overall system configuration management. As an illustration of the iterative nature of an advanced system development project, the system development history of the HiMAT program is summarized in figure 4.

The software control and system configuration management process proved to be an effective and efficient method to track, document, and manage this advanced aircraft system development activity. The capability of this process to accurately and efficiently manage the development of a highly integrated flight system containing multiple, diverse subsystems with an overall systems-wide approach was again demonstrated.

CONCLUDING REMARKS

An effective software control and system configuration management process for flight-critical digital control systems of advanced aircraft has been described and illustrated. The process has been successfully applied to a number of programs involving research aircraft and remotely piloted research vehicles with advanced flight control systems. Key factors to be considered in the development of a software control and system configuration management process that works include:

1. The highly complex interactions among the hardware, software, and system elements of a state-of-the-art digital flight control system design require that a systems-wide approach be used for configuration control and management.

2. Application experience has shown that maintenance of separate hardware and software configuration control procedures is ineffective for highly integrated flight systems in that many of the difficult design, development, and testing issues involve interactions between hardware and software systems.

3. The implementation of a configuration management process must account for the fact that all the primary system development phases are likely to require iterative development over the lifespan of a complex flight system.

The primary purpose of the software control and system configuration management process for flight-critical digital control systems is to provide a method for efficient system development and a process for assuring safe flight operations. The principal elements of the process include: (1) procedures for reporting, tracking, and reconciling all system hardware and software discrepancies; (2) a structured process for identifying, reviewing, and implementing system hardware and software configuration changes; (3) rigorous system verification and validation test procedures; (4) accurate and consistent documentation requirements; and (5) an active and knowledgeable configuration control board to review and approve all system configuration modifications.

The effectiveness and flexibility of this software control and system configuration management process has been demonstrated in use on several advanced flight system development programs of varying complexity and diverse configurations.

APPENDIX - CONFIGURATION MANAGEMENT FORMS

This appendix includes examples of typical forms used in the systems configuration management documentation and tracking process: Discrepancy Report, Configuration Change Request, Work Order, Program Change, and System Test Report.

DISCREPANCY REPORT (DR)

– REPORT GROUND-BASED OR AIRBORNE PROBLEM WITH HARDWARE, SOFTWARE, OR ASSOCIATED OPERATION.
– SEE PROCESS SPECIFICATION 00-7 FOR DETAILS

(1) DR NO:	(2) SITE	(3) ASSIGNED TO:	(4) CRITICALITY:

PART A – AIRCRAFT/FACILITY PORTION OF DR

(5) ACFT/FACILITY:	(6) ACFT SER NO:	(7) FLT NO:	(8)

(9) DISCREPANCY – List ALL symptoms: | (10) MO/DY/YR | (11) FLT/OP HRS | (12) FW STATUS | (13) SIGNATURE/ORG/SITE

FAILURE 1ST SUSPECT

(14) FINDINGS OF DETAILED FAILURE ANALYSIS – Root Causes: | (15) MO/DY/YR | (16) FLT/OP HRS | (17) FW STATUS | (18) SIGNATURE/ORG/SITE

FAILURE CAUSE FOUND – Details Listed Above

(19) CORRECTIVE & CLOSING ACTIONS: | (20) PCN'S, CCR'S WO'S, etc. | (21) MO/DY/YR | (22) FLT/OP HRS | (23) FW STATUS | (24) SIGNATURE/ORG/SITE

ACFT/FACILITY CLOSEOUT ACTION COMPLETE

(25) ACFT/FACILITY CLOSEOUT SIGNATURE:	(26) MO/DY/YR:	(27)	(28) ACFT/FACILITY CLOSEOUT SIGNATURE	(29) MO/DY/YR	(30)

PART B – ☐ SUB-ASSY PORTION OF DR. USE FOR HARDWARE OR SOFTWARE. USE 1 PART B FOR EACH MAJOR OR LOWER ASSY

(31) ITEM WUC:	(32) ITEM NAME:	(33) ITEM PART NO:	(34) ITEM SER NO:

(35) DISCREPANCY – List ALL symptoms not previously listed: | (36) MO/DY/YR | (37) OP HRS/CYC | (38) FW STATUS | (39) SIGNATURE/ORG/SITE

FAILURE 1ST SUSPECT

(40) FINDINGS OF DETAILED FAILURE ANALYSIS – List findings not previously listed: | (41) MO/DY/YR | (42) OP HRS/CYC | (43) FW STATUS | (44) SIGNATURE/ORG/SITE

FAILURE CAUSE FOUND – DETAILS LISTED ABOVE

(45) CORRECTIVE & CLOSING ACTIONS NOT PREVIOUSLY LISTED: | (46) PCN'S, CCR'S, WO'S, etc. | (47) MO/DY/YR | (48) OP HRS/CYC | (49) FW STATUS | (50) SIGNATURE/ORG/SITE

ITEM CLOSEOUT ACTION COMPLETE

(51) ITEM CLOSEOUT SIGNATURE:	(52) MO/DY/YR:	(53)	(54) ITEM CLOSEOUT SIGNATURE:	(55) MO/DY/YR	(56)

CONFIGURATION CHANGE REQUEST

CCR NO.			
PROJECT	INITIATOR	ORGANIZATION	DATE
PROJECT TEAM REP.	D.R. NO. (REF.)	W.O. NO. (REF.)	P.C. NO. (REF.)

REQUEST:

EVALUATION AND ASSESSMENT

APPROVE ☐	DISAPPROVE ☐	RETURN FOR ANALYSIS ☐
FOR RELEASE	CCB OFFICIAL	DATE

SIG ______________________ DATE __________ SIG ______________________ DATE __________

REMARKS

STR NO.

Work Order

(1) DATE OF REQUEST:	(2) WORK ORDER NUMBER:		(3) SUB-TASK:	
(4) DATE REQUIRED:	(5) STARTED:	(6) COMPLETED:	(7) INSP:	
(8) ORIGINATOR: TELEPHONE:	(9) TO:			
(10) PROJECT:	(11) ATTACHMENTS: NO ____ YES ____ If YES, list each attachment at BOTTOM of WORK ORDER			
(12) APPROVALS: (a) signature title date	(c) signature title date			
(b) signature title	(d) signature title date			

(13) ITEM No.	(14) DESCRIPTION OF WORK	(15) DATE	(16) TECH.	(17) INSP.
	LIST ATTACHMENTS			
	ORIGINATOR			

PROGRAM CHANGE
SOFTWARE CHANGE CONTROL

REQUEST	NOTICE	IF REQUEST, DATE DOCUMENTATION UPDATED SIG: DATE:	PC NO.

TITLE	DATE

CHANGE TO REL.	S/N	ORIGINATOR/ORG.

DR NO	MODULES/SUB ROUTINES CHANGED	CCR NO. (REF.)

SPECIFICATION REV. NO	VERIFICATION AND VALIDATION COMPLETE: SIG: ______________________ DATE: __________

DESCRIPTION OF CHANGE

REASON FOR CHANGE

IMPACT ANALYSIS

MEMORY	TIMING	MODULES

REMARKS

SIG: ______________________________ DATE: ______________________________

SYSTEM TEST REPORT

TITLE				NUMBER	DATE
ORIGINATOR/ORG			RELEASE	SYSTEM CONFIGURATION	

OBJECTIVE

CONT'D ON PAGE ________

TEST SETUP

SIG: DATE:

CONT'D ON PAGE ________

SUMMARY RESULTS

SIG: DATE:

CONT'D ON PAGE ________

CONCLUSIONS

SIG: DATE:

CONT'D ON PAGE ________

RETEST REQUIRED	YES	NO	DR ISSUED	DATE	NO.

REMARKS

SIG: DATE:

W.O. NO. (REF.)	PC NO. (REF)

REFERENCES

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2. Szalai, Kenneth J., Jarvis, Calvin R., Krier, Gary. E., Megna, Vincent A., Brock, Larry D., and O'Donnell, Robert N. Digital Fly-by-Wire Flight Control Validation Experience. NASA TM-72860, 1978.

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4. Petersen, Kevin L. Flight Control Systems Development of Highly Maneuverable Aircraft Technology (HiMAT) Vehicle. AIAA Paper 79-1789, Aug. 1979.

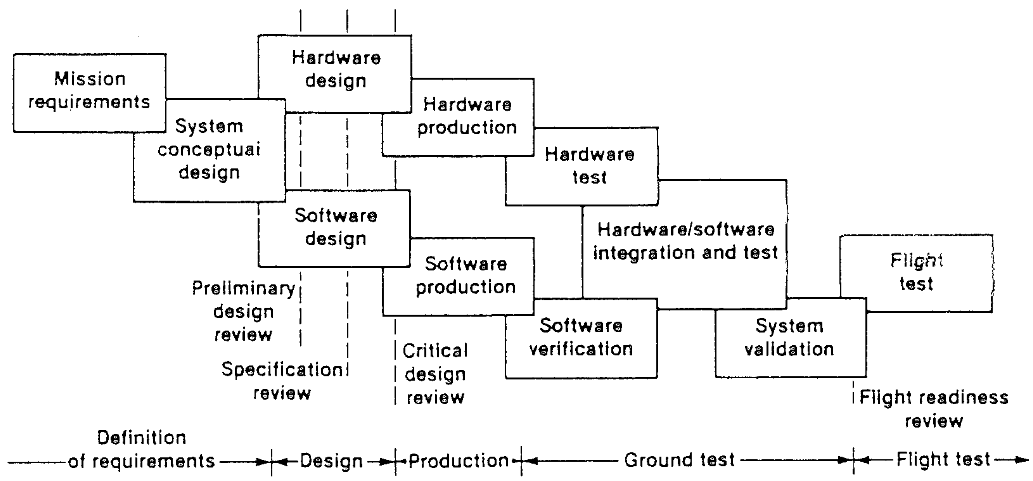


Figure 1. System development phases.

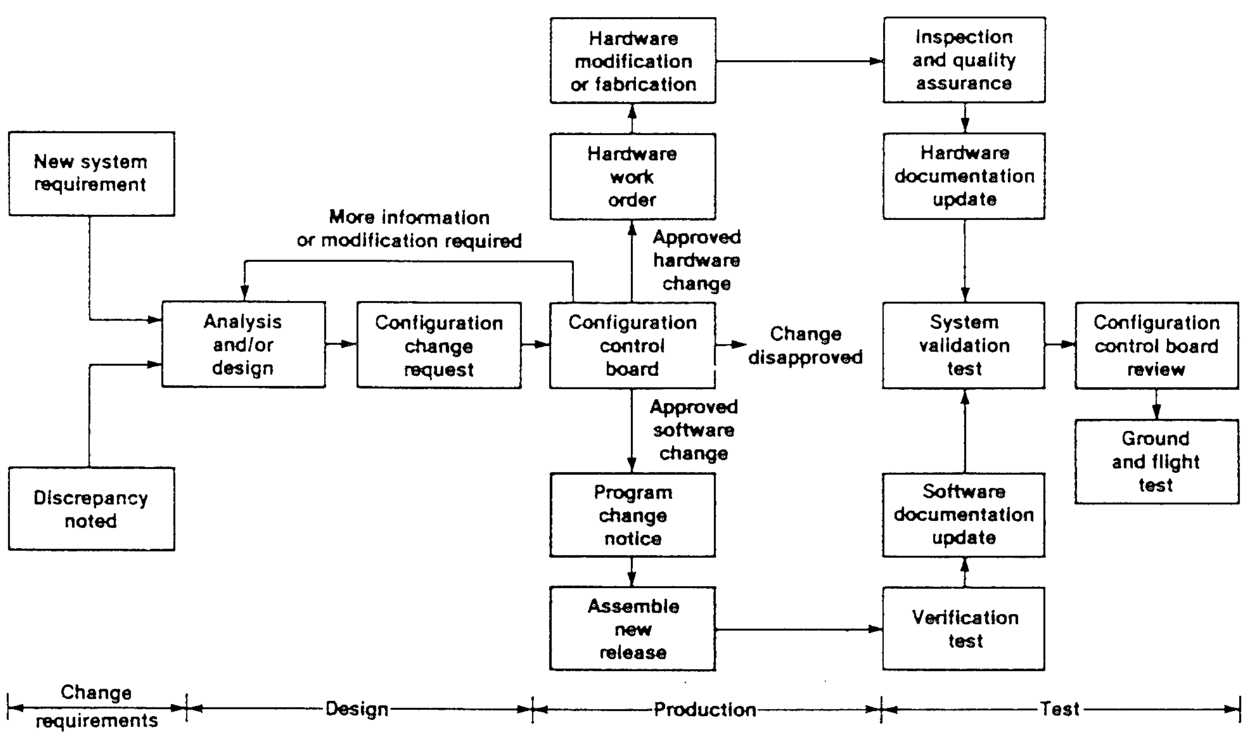


Figure 2. Software control and system configuration management process.

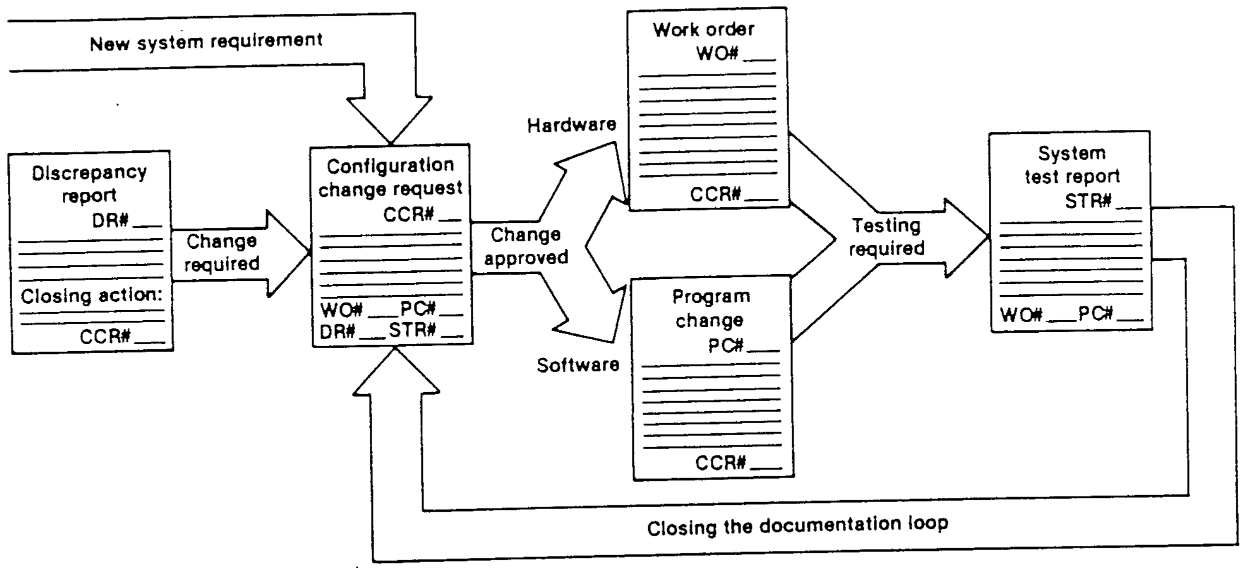
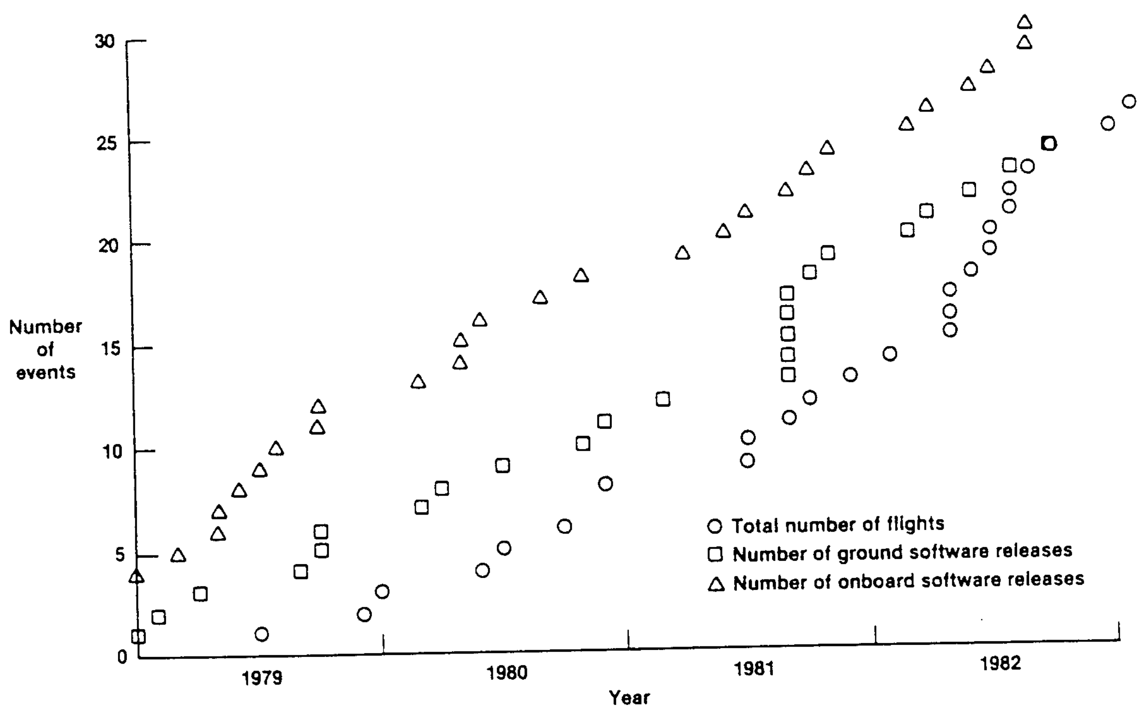
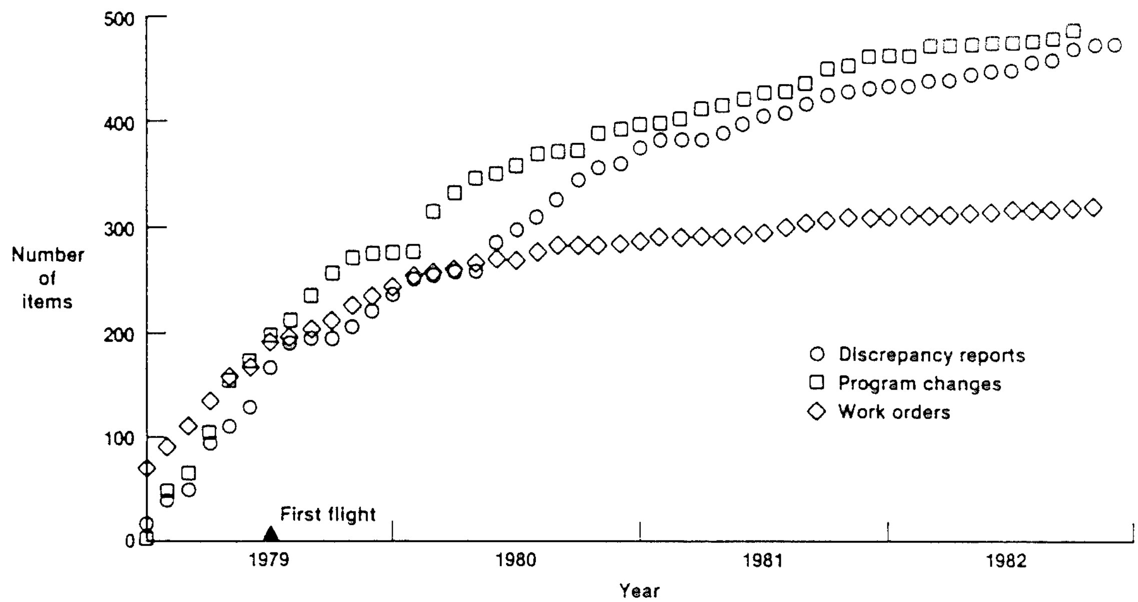


Figure 3. Documentation flow and tracking process.



(a) Flights and software releases.

Figure 4. HiMAT system development history.



(b) Discrepancy reports, program changes, and work orders.

Figure 4. Concluded.

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4. Title and Subtitle Software Control and System Configuration Management: A Systems-Wide Approach		5. Report Date August 1984
		6. Performing Organization Code
7. Author(s) Kevin L. Petersen and Christobal Flores, Jr.		8. Performing Organization Report No. H-1256
		10. Work Unit No.
9. Performing Organization Name and Address NASA Ames Research Center Dryden Flight Research Facility P.O. Box 273 Edwards, California 93523		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
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15. Supplementary Notes

This report is a revised version of an IEEE/AIAA paper presented at the IEEE/AIAA 5th Digital Avionics Systems Conference, Seattle, Washington, Oct. 31 - Nov. 3, 1983. It includes examples of configuration management forms.

16. Abstract

A comprehensive software control and system configuration management process for flight-critical digital control systems of advanced aircraft has been developed and refined to ensure efficient flight system development and safe flight operations. Because of the highly complex interactions among the hardware, software, and system elements of state-of-the-art digital flight control system designs, a systems-wide approach to configuration control and management has been used. Specific procedures are implemented to govern discrepancy reporting and reconciliation, software and hardware change control, system verification and validation testing, and formal documentation requirements. An active and knowledgeable configuration control board reviews and approves all flight system configuration modifications and revalidation tests. This report includes examples of configuration management forms and a description of the tracking process which ensures accurate and consistent records. This flexible process has proved effective during the development and flight testing of several research aircraft and remotely piloted research vehicles with digital flight control systems that ranged from relatively simple to highly complex, integrated mechanizations.

17. Key Words (Suggested by Author(s)) Configuration management Software change control	18. Distribution Statement Unclassified-Unlimited STAR cataegory 05

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APPENDIX F

ARMY TACTICAL MISSILE SYSTEM CM

7.5 **INITIAL OPERATIONAL TEST AND EVALUATION (IOT&E)(OPTION).** The contractor shall fabricate and deliver four Block II missiles that replicate the production configuration of the missile. The contractor shall provide field team support to process missiles for flight. The contractor shall also provide support of flight test activity at WSMR Control Center and at the launch site. The Government will establish and publish restrictions related to the contractor's test support. The contractor's support shall conform to all of these restrictions. The contractor shall also respect and abide by directions and decisions of the operational test conductor. When requested, the contractor shall employ diagnostic failure analysis and reporting techniques for analyzing and reporting hardware and software failures encountered during the IOT&E.

7.6 **RANGE SAFETY.** The contractor shall support preparation of National Range Documentation, and comply with WSMR Range Safety and missile flight test planning requirements. Missile flight test planning shall include support for preparation of Range Safety Data to meet WSMR requirements. Missile destruct procedures, reaction times, and debris footprints shall be developed.

7.7 **SURFACE DANGER AREA.** Prior to test firings (including sled testing), an interim surface danger area, defined to a one-in-one million escapement probability criteria, shall be constructed utilizing Army TACMS Block I methodology. Both normal and malfunctioning modes, assumptions made, and a description of the system behavior for each malfunction possible and probability of occurrence shall be included. The final surface danger area assessment shall be derived from the data used for the interim footprint, flight data, and data derived from simulations and flight characteristics with the integration of the BAT submunition. The final surface danger area shall also include a one-in-one-hundred-thousand escapement probability footprint. The interim and final surface danger areas shall be included as an appendix to the SAR.

8.0 **CONFIGURATION MANAGEMENT.**

8.1 **FUNCTIONAL BASELINE (FBL).** The FBL for the Army TACMS Block II continued development shall be the Army TACMS system specification, MIS-38578 Addendum II.

8.2 **REQUESTS FOR OFFICIAL MILITARY NOMENCLATURE.** The contractor shall prepare and submit to the procuring activity requests for nomenclature for major end items and their principle components which are to be type classified.

8.3 **CHANGES TO GOVERNMENT CONTROLLED DOCUMENTATION.** Changes to documentation under Government control shall be incorporated only after Government approval of Engineering Change Proposals (ECPs). The contractor shall assign ECP numbers obtained from the Government. Notices of Revision (NORs) shall be prepared for each affected drawing or specification and shall be included as an integral part of the ECP.

8.4 **METRICS.** All data and documents developed under this SOW shall utilize metric units.

8.5 **DOCUMENTATION STORAGE AND CONTROL.** The contractor shall have custodianship of all technical documentation generated and/or maintained under this SOW and shall utilize a central fireproof repository appropriate for accommodating all original and master documentation and computer tapes or other media. The contractor shall establish and maintain control access to these data IAW the documentation storage and control portion of the CMP.

8.6 **DELIVERY OF DRAWINGS.** Unclassified/unlimited rights data to be submitted to the Government repository shall be in raster image format(on magnetic tape [9-track 1600/6250 bits per inch [BPI] fully compatible with MICOM DIGITAL STORAGE AND RETRIEVAL ENGINEERING DATA SYSTEM [DSREDS], compression is Comite' Consultatif International de Telegraphique et Telephorique [English: International Consultative Committee on Telegraphy and Telephony] [CCITT], group-4, non-wrap format, document identifier record is specified in the attachment to Document Summary List [DSL], document type codes same as for aperture cards) or microfilm aperture format (compatible with and IAW DESREDS requirements, from document originals, as sets in numerical sequence). Classified/limited rights data shall be delivered in microfilm aperture card format only. Each shall be marked appropriately to identify the data contained within.

9.0 **PRODUCT ASSURANCE.**

9.1 **MAJOR NON-CONFORMANCES.** All critical and major non-conformances shall be processed through formal materiel review board procedures. The procuring activity reserves the right of approval for material review board determinations related to critical and major non-conformances.

9.2 **PROHIBITED PARTS, MATERIELS, AND PROCESSES (PMPs).** A listing of prohibited PMPs is found at attachment 07.

9.3 **HARDWARE/SOFTWARE VALIDATION.** All special inspection equipment (SIE) and special test equipment (STE) and their associated software shall be validated by the procuring activity prior to use for acceptance of hardware.

10.0 **INTEGRATED LOGISTICS SUPPORT (ILS).**

10.1 **PROGRAM REQUIREMENTS.**

a. The contractor shall implement the Integrated Support Approach that is a part of this contract. The contractor shall conduct a logistics demonstration.

b. The Government shall periodically review and/or audit contractor adherence to integrated logistics support processes established by the contractor for the performance of the Block II program. Depending on the results of these reviews, the Government may issue recommendations for process improvement (CIOs) or provide NODs. The contractor shall be responsible for developing and implementing corrective action plans to return contractor processes to control.

10.2 **SYSTEM SUPPORT PACKAGE (SSP) FOR DEMONSTRATIONS AND TESTING.** The contractor shall assemble and deliver all items/equipment identified on the SSPCL and deliver to the test sites 30 days prior to the scheduled start date of each test.

10.3 **LOGISTICS SUPPORT ANALYSIS\LOGISTICS SUPPORT ANALYSIS RECORD (LSA/LSAR).** The contractor shall perform LSA during the integration of the BAT submunition. The LSA performed on Army TACMS Block II shall be consistent with the existing Army TACMS Block IA program. LSA shall also be performed on modifications to the M270 launcher and MLRS training and support equipment to support Block II application, and shall be consistent with existing M270 launcher data base.

10.4 **BLOCK II DOCUMENTATION/STORAGE/ACCESS REQUIREMENTS.**

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH DEVELOPMENT AND ACQUISITION
103 ARMY PENTAGON
WASHINGTON, DC 20310-0103

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The Army is committed to acquisition excellence through acquisition reform and improvement. To improve productivity and move toward a paperless environment, the following is effective immediately for all Army components: where possible for each data item to be delivered under a contract, only one copy shall be specified with a single delivery point and a single destination point. It is preferred and strongly encouraged that data items be delivered using electronic media.

[redacted]

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ARMORED SYSTEMS MODERNIZATION
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FIELD ARTILLERY SYSTEMS
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STANDARD ARMY MANAGEMENT INFORMATION SYSTEMS
TACTICAL MISSILES
TACTICAL WHEELED VEHICLES
MISSILE DEFENSE

DIRECTOR, ARMY ACQUISITION EXECUTIVE SUPPORT AGENCY
JOINT PROGRAM OFFICE, BIOLOGICAL DEFENSE

APPENDIX G

LORAL SPACE INFORMATION SYSTEMS

SPACE SHUTTLE ONBOARD SOFTWARE
PROGRAM MANAGEMENT
AND
CONFIGURATION CONTROL
PROCESS

1. SPACE SHUTTLE ORBITER AVIONICS SOFTWARE

1.1 INTRODUCTION

The purpose of the Space Shuttle Orbiter Avionics software is to provide the means of bringing the essential but diverse portions of the Orbiter together into a system which responds to the demands of its users. The software development process is managed to ensure that the delivered product provides the required functions and services and is only changed under controlled conditions. This plan provides an overview of the software development process and the management approach which the IBM Corporation uses to assure that quality software products are provided to NASA according to schedule.

1.1.1 Purpose

This document provides IBM's management approach for the development of the Space Shuttle Orbiter Avionics software to support the Operational Flight phase. The software development process as described in this document includes software maintenance. All processes are identical for development and maintenance except for authorizing document and approval processes.

1.1.2 Scope

This process is applicable to the development, verification, and certification of the Onboard Space Shuttle Orbiter Avionics software.

1.2 RESPONSIBILITIES

The development and maintenance of the Space Shuttle Orbiter Avionics software is the responsibility of IBM in response to NASA supplied requirements. For functional capability development, IBM responds to software Change Requests (CRs) approved by the Shuttle Avionics Software Control Board (SASCB) of the NASA Project Office (PO). IBM also has the responsibility for the development and maintenance of Flight Software Application Tools (FSWAT). FSWAT is the set of software tools that supports the development and reconfiguration of the Flight Software. Changes to the FSWAT are governed by Support Software Change Requests (SSCRs) and Support Software Discrepancy Reports (SSDRs). Both FSW and FSWAT changes are packaged into Operational Increments (OIs) and implemented and tested by IBM in the Software Development Facility (SDF). It is the responsibility of IBM to completely test each of these increments in preparation for subsequent reconfiguration prior to being used to support STS flights. Formal review and acceptance of the implementation and testing of each OI is the responsibility of the NASA Spacecraft Software Division (SSD). IBM participates in the configuration inspection (CI) chaired by NASA/SSD. CI is held for each OI following completion of the independent verification phase of the development

For flight to flight reconfigurations, IBM is responsible for the certification of the PASS FSW. IBM independently produces a reference Mass Memory and compares the final products as well as some intermediate products, to Space Transportation System Operations Contract's (STSOC's) Mass Memory. Miscompares are analyzed and corrected as required. Furthermore, formal testing is performed on the flight Mass Memory to verify the flight readiness before IBM signs the Flight Readiness Statement.

Certification is only applicable to PASS Reconfiguration builds of deliverable products specified by the Mass Memory Integration Plan (MIP) as delimited by the FRONTROOM BACKROOM INTERFACE CONTROL DOCUMENT (ICD).

1.3 PROJECT MANAGEMENT

1.3.1 Project Manager

The project manager is responsible for ensuring that the software being designed, developed and tested for the Space Shuttle Orbiter Avionics meets the requirements and objectives established by NASA. The project manager also ensures adherence to processes, procedures, and configuration management. Full compliance with these items is indicated with the project manager's signing of the Certification of Flight Readiness (COFR) for each shuttle mission. To achieve these objectives the project manager has organized a project-oriented organization (see Figure 1-1 on page 1-3). This organization ensures that management has access to and control of all resources necessary to meet schedules and performance objectives. The Software Quality Assurance (SQA) organization is independent of the OBS project and management.

1.3.2 Onboard Space Shuttle

The project manager is responsible for the development of all Primary Avionics Software System (PASS) capabilities, certification of all flight systems, and the development of application support software systems used in the preparation of the flight systems. The maintenance of project baselines and schedules is accomplished through a project-wide Backroom Baseline Control Board (BBCB). The chair person of the BBCB is a staff function reporting directly to the Project Coordination Manager. Members include second level management and key staff personnel from all appropriate areas. The charter of the BBCB is threefold:

- Define, negotiate and baseline project-wide development, build, test and delivery schedules
- Control and baseline flight software change baselines (Change Requests and Discrepancy Reports)
- Coordinate interproject technical issues

The organizational structure involves six major areas. The areas correspond to the following general activities and are described in detail in the following paragraphs:

- Development and maintenance of new and existing flight software capabilities
- Verification of flight software capabilities
- Flight operations support
- Flight reconfiguration certification
- Development and test of support software systems
- System build

1.3.2.1 Avionics Software Development

The Avionics Software Development organization is responsible for the development of enhancements and maintenance to flight software applications and operating system capabilities. These software enhancements are defined by the NASA PO Shuttle Avionics Software Control Board (SASCB) via CRs. In collaboration with NASA PO and SSD, these changes are packaged into software systems called OIs and nominally developed on six month centers. In general, a single OI will support multiple STS flights with software releases called OF's.

In addition to development, the organization is also responsible for software system architecture and memory analysis.

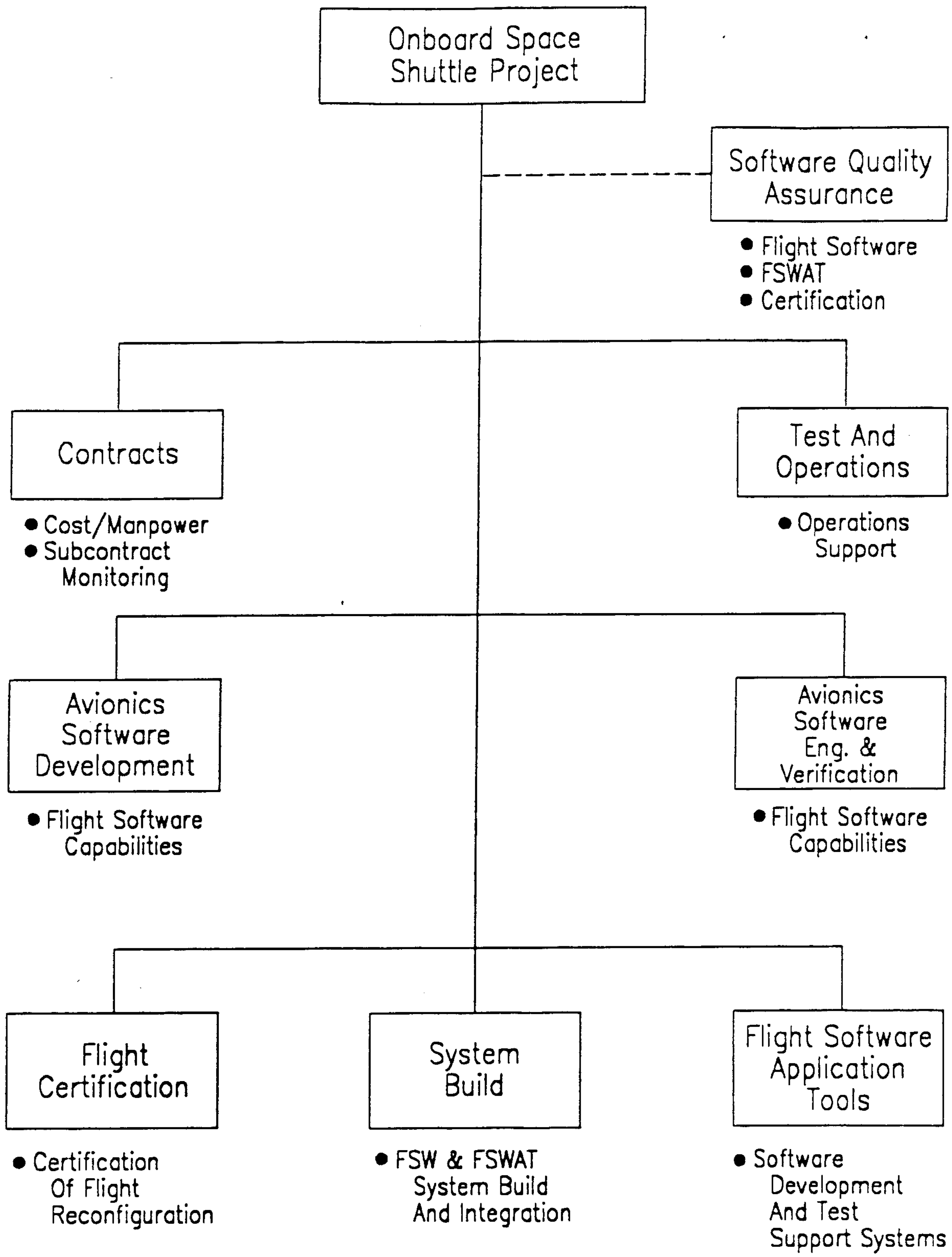

Figure 1-1. Onboard Space Shuttle Project Organization

1.3.2.2 Avionics Software Engineering and Verification

The verification organization is responsible for the test of enhancements to the flight software and operating system. Each OI is tested and made available for reconfiguration, i.e., the application of mission and payload specific data.

The Engineering organization is responsible for reviewing all proposed requirements changes to the flight software to ensure that the software can perform properly (Central Processing Unit (CPU) timing measurements, etc.). and meet desired flight objectives.

1.3.2.3 Test and Operations

The Test and Operations (T&O) organization supports installation and maintenance of delivered systems in the users sites which include, the orbiter vehicle and test facilities at the Kennedy Space Center (KSC), the Shuttle Mission Simulator in Houston, the Shuttle Avionics Integration Laboratory in Houston, the KSC Automated Test Set, the Cargo Integration and Test Equipment at KSC, the JSC Avionics Engineering Laboratory (JAEL), and other sites as required.

1.3.2.4 Flight Software Application Tools (FSWAT)

The Flight Software Application Tools organization is responsible for building software used for the development, reconfiguration, and test of PASS Flight Software. The types of software produced include: flight simulation, preprocessors, post-processors, build and data analysis tools. FSWAT is also responsible for maintaining the software configuration management data bases. The major functions performed by FSWAT include: writing requirements, generating design and code, performing unit test and verification, and generating and publishing User's Guides and requirements documents for the produced software.

1.3.2.5 System Build

The System Build organization is responsible for building FSW and FSWAT systems from source. It also performs all the flight-to-flight Reconfiguration Certification builds. This group assures that all developed software changes are put on systems in a controlled fashion. Other functions performed by this group include building integrated Mass Memories and generating software deliverables.

1.3.2.6 Contracts

The contracts department is primarily responsible for cost/manpower monitoring, analysis and reporting. In addition, the department is also responsible for subcontract monitoring and GFE and IBM property administration and control.

1.3.2.7 Flight Certification

The Certification task is performed in parallel with but not in line to the STSOC reconfiguration process. IBM independently builds a Mass Memory. This Mass Memory is compared with the one built by STSOC and the results are reported to SSD. The STSOC Mass Memory is then copied over the IBM build Mass Memory so that independent testing can be performed on the Flight Mass Memory. Results of this testing is reported to SSD through a formal Certification Test Review (CTR). IBM signs the Flight Readiness Statement to denote that the PASS FSW is certified.

1.3.3 Software Quality Assurance (SQA)

The independent SQA organization has the responsibility for assuring that all software development phases of the contract are conducted in accordance with the requirements and standards specified in the contract and any applicable IBM imposed requirements. The SQA personnel are responsible for assuring the following:

1. Preparation of Software Quality Assurance Plans (SQAP)
2. Direction of program quality assurance efforts
3. Coordination with DCASPRO, customer and subcontractor representatives on quality matters
4. Auditing the accomplishment of the SQAP requirements.

1.4 MANAGEMENT CONTROLS

To insure management control of flight and support software development and certification activities the Onboard Space Shuttle project utilizes the following mechanisms:

- A series of internal IBM control boards with direct interfaces to corresponding NASA control boards (see Figure 1-2 on page 1-6)
- A rigorously controlled Configuration Management Data Base (CMDB) containing release contents (Requirements changes, discrepancy corrections) under the control of the IBM board chairmen (see Figure 1-3 on page 1-7)
- A series of weekly and bi-monthly status and policy meeting with various levels of IBM and NASA/Spacecraft Software Division management
- Weekly and bi-monthly publication of baselines, project and detailed schedules and development plans including the IBM-internal BBCB datapack which provides a comprehensive project summary.

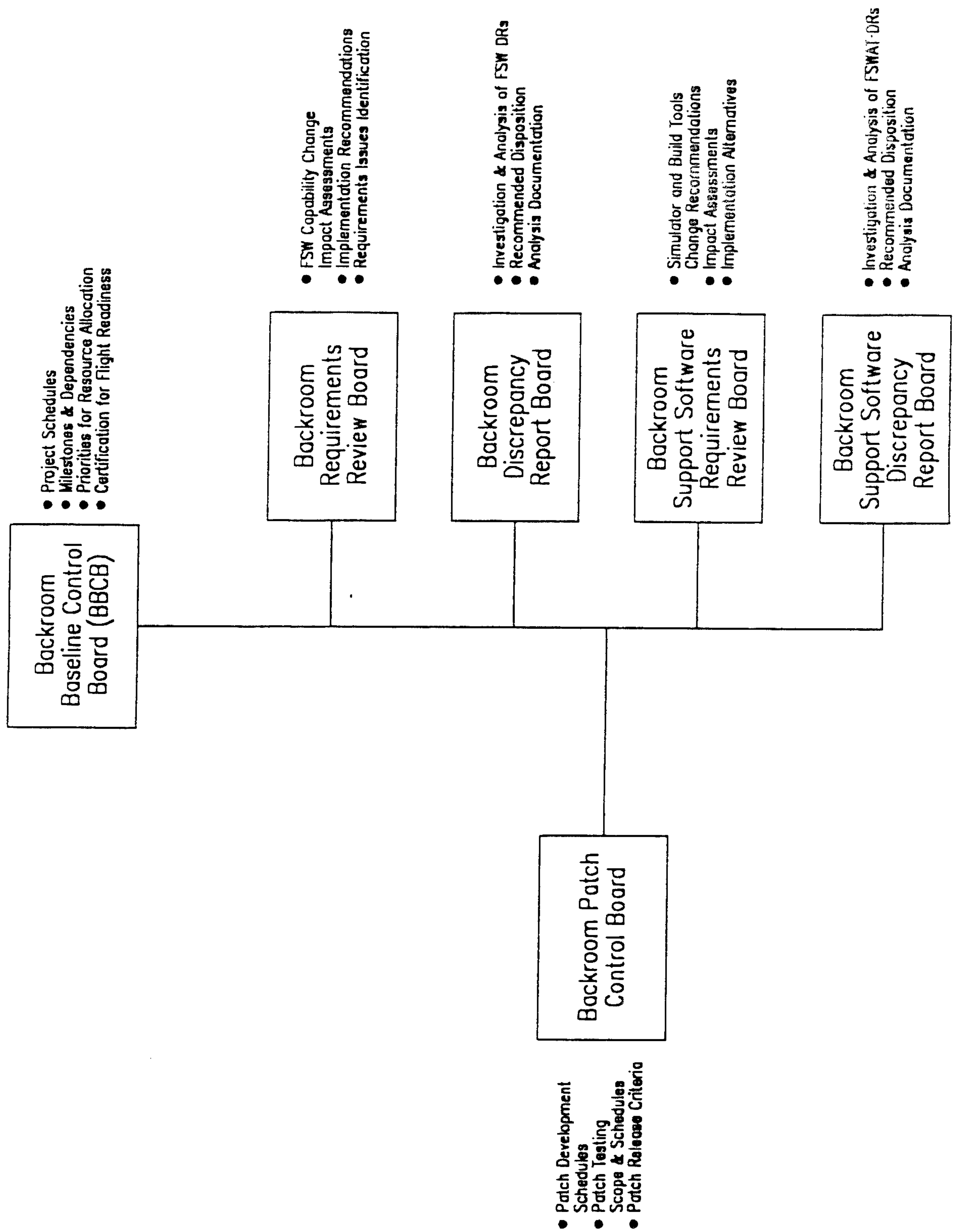

Figure 1-2. IBM Control Boards

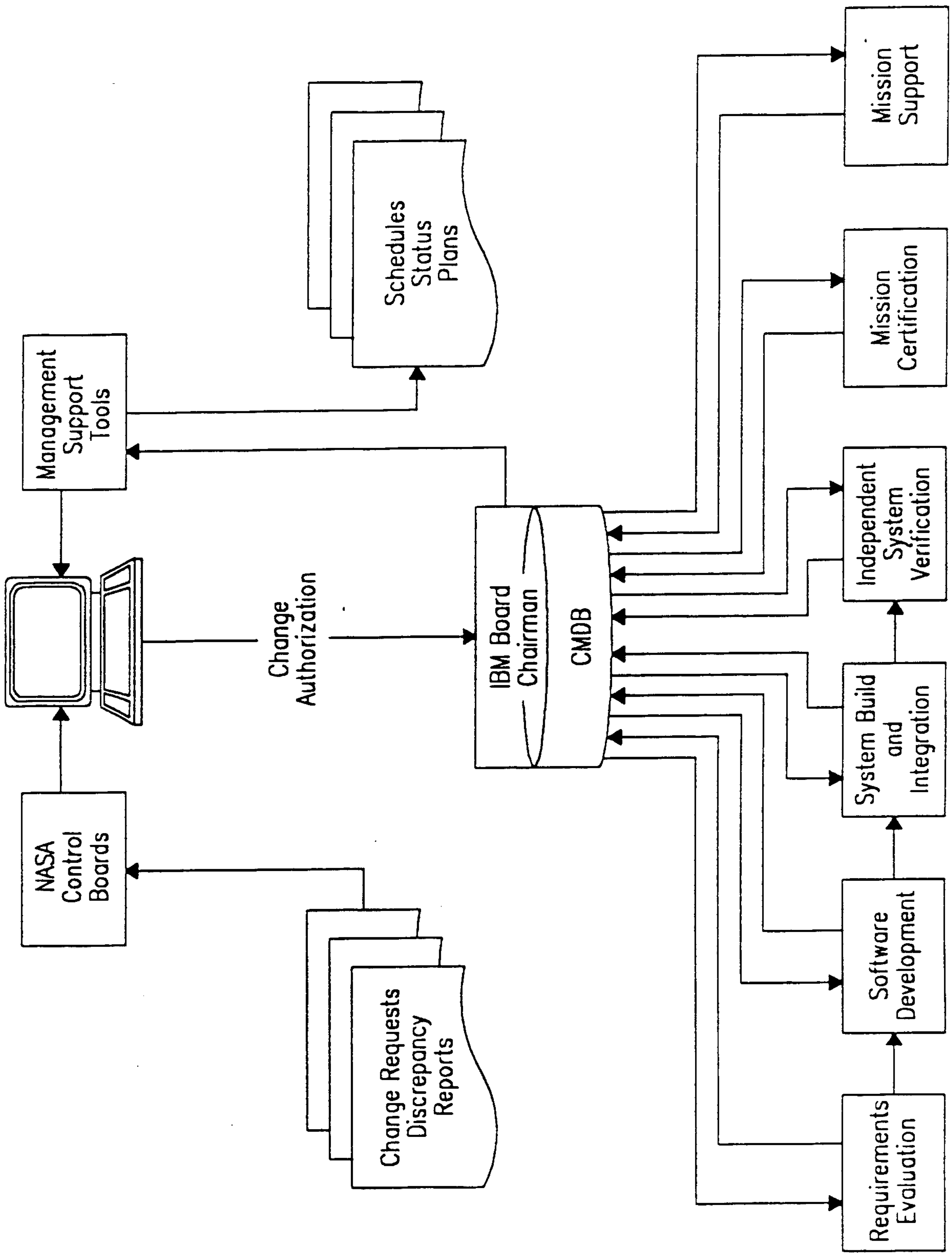

Figure 1-3. Software Development Process

6. CONFIGURATION MANAGEMENT

Configuration management is the process of authorizing and documenting every modification to each product end item. This is accomplished through the use of two procedural concepts: configuration control and configuration management tools.

6.1 CONFIGURATION CONTROL

Configuration control is the establishment of technical control points called baselines and the systematic evaluation, coordination, and disposition of all proposed changes to these baselines. The management of configuration control within IBM is the primary responsibility of the Backroom Baseline Control Board (BBCB) to coordinate the overall project configuration elements so that each activity element is efficiently integrated with the rest of the project.

6.1.1 Project Configurations

The BBCB convenes regularly with management and key staff personnel from all appropriate areas to compare actual status and scheduled milestones. The following baselines are reviewed and revised or rescheduled as necessary by the BBCB in order to support both the other project activities and product commitments:

a. Active flight software systems available
b. Active simulator systems available
c. Flight software build and release schedules
d. Flight software build and release contents
e. Simulator software build and release schedules
f. Simulator software build and release contents
g. Certification build and compare schedules
h. Support hardware configurations
i. Computer time schedules
j. Configuration management data base (CMDB) contents
k. Receipt dates for government and STSOC furnished input data items
l. Commitments to the customer (NASA)

The flight software and the Flight Software Application Tools (FSWAT) configuration control is delegated to four sub-boards which report to the BBCB. Those boards are: the Primary Avionics Software System (PASS) Discrepancy Report (DR) Review Board, the Requirements Review Board (RRB) which maintains requirements Change Request (CR) configuration control for the PASS, the Support Software Review Board (SSRB) which maintains CR configuration control for FSWAT, and the Support Software DR Board (SSDRB).

6.1.2 Flight Software

The PASS DR Board is charged with the responsibility of reviewing and reporting on the results of each suspected flight software error identified. Recommendations are made to NASA as to the resolution of each such problem. NASA is then responsible for approving or disapproving the recommended action for each discrepancy. In cases where changes in PASS requirements are involved, the RRB is the reviewing and reporting board. Modifications to the CR baseline are determined by the NASA control board approvals of the new requirements. Maintenance of the PASS CR baseline within IBM is the responsibility of the RRB.

6.1.3 Flight Software Application Tools (FSWAT)

The Support Software Requirements Control Board (SSRB) within the FSWAT organization is responsible for FSWAT requirements and maintenance. These responsibilities are described in Sections 3.2.2 and 3.6, respectively.

6.2 CONFIGURATION CONTROL DOCUMENTS

Changes to the PASS or FSWAT software are documented as either DRs or CRs. CRs are initiated when a program requirement has changed. A DR is initiated when known or suspected errors are detected in the software requirements, design, or code. DRs and CRs may be originated by NASA, IBM, or any using agency of IBM end items.

Each DR or CR is logged into the CMDB and forwarded to the line organizations of software development and software verification for assessment. Their assessment is reviewed by the appropriate CR or DR review board where basic recommendations of disposition and implementation are made. The review board determines the recommendation to be presented to NASA. The final approval is received via the NASA control boards. Subsequent handling of the report or change is done by the line organizations to perform modifications in the software as required after which the DR or CR is closed. The status of the report or request during the cycle is maintained in the CMDB.

6.2.1 Change Requests

A CR is initiated when a change to a baseline requirement is proposed or a discrepancy other than an implementation error has occurred. Requests may be originated by NASA, Rockwell, IBM, or other contractors. Information about the change includes a description, justification, computer program end item baseline impacted and affected software areas. Agencies external to IBM originating CRs submit them to NASA. IBM originated CRs go to the RRB and then to NASA Spacecraft Software Division (SSD). The change is assigned a control number by NASA.

Once an IBM originated CR has received RRB approval it goes to the SSD Change Control Board (CCB) with other non-IBM generated CRs. A CCB approved CR must then be approved by the SASCB before IBM is directed to implement it. At that time the CR is scheduled in the CMDB and baselined for a specific software release system. The CMDB then serves as the baseline for each software system. Updates to the software can only be performed for approved change authorities as designated in the CMDB.

The CMDB is the baseline against which independent verification builds their test plans. All change authorities are specifically verified.

6.2.2 Discrepancy Reports

Any user at any test facility or operational site in which the PASS software or the FSWAT software is in use may originate a DR to identify a known or suspected software error.

Information about the error is recorded by the originator and includes identification of the suspected module and the system being used, conditions at time of error, and a specific description of the error. Any agency which uncovers an error supplies the information about the error on a DR form with a unique control number which identifies the discrepancy in subsequent activity. IBM sends a copy of the discrepancy to NASA for review and enters it into the CMDB. An analysis sheet containing a full discussion of the analysis and the effects of the problem is added to the DR once resolved. IBM maintains these documents for future reference. Once IBM and NASA agree that a DR should be resolved via a software change, that change is scheduled in the CMDB for an appropriate release. The CMDB then serves as the baseline for each software system. Updates to the software can only be performed for approved change authorities as designated in the CMDB.

The CMDB is the baseline against which independent verification builds their test plans. All change authorities are specifically verified.

6.3 CONFIGURATION MANAGEMENT TOOLS

6.3.1 Configuration Management Data Base (CMDB)

The CMDB is the repository for the control and descriptive information relating to project CRs or DRs. The designation "change request" includes any and all control instruments (e.g., CRs, SSCRs) authorizing changes to project requirements or baseline items. DRs authorize changes when project software systems or procedures do not conform to requirements. The CMDB provides the mechanism for management, tracking, and control of flight software, support software, and test software in both the Shuttle Software development and production environment. Build programs which create or modify permanent (baseline) segments in system data bases (e.g., Development System Base (DSB) and mission data base) do so under the authority of approved CRs and DRs as found in the CMDB. The CMDB is maintained by the configuration management and control functions as the centralized storage facility for all relevant change control data. It serves as the source of status query responses and status report generation. In addition, it maintains a limited cumulative change history of other system data bases.

6.3.2 Member Name Implementation Data Base (MNIDB)

The Implementation Data Base (IDB) represents a central repository for storing FSW and FSWAT support software data related to an associated DSB or Mission System Base (MSB), the KEPT library, or a mission data base (MDB). An IDB associated with a DSB or MSB contains manually supplied PASS and FSWAT information referred to as descriptive data. This data represents information supplied by designers, developers, and verifiers and contains information such as program ownership and processing instructions, performance criteria, and/or hidden cross references in the software. Both DSB MSB and IDBs contain FWS and its support software descriptor data for all combinations of features that they are required to support. An IDB associated with an MDB initially contains only the descriptor data for that subset of MSB IDB names required in support of the mission being built. This includes all member names unaffected by features as well as those member names affected by the selected feature set associated with the mission. Subsequent data is added to an IDB in an MDB as a result of mission reconfiguration activities when, for example, load module and MMU addresses are installed following linkage editor and MMU build activities, or when I-Load values are installed for specific FSW variables following execution of the I-Load Preprocessor. KEPT IDBs contain, instead of normal baseline segments, pool elements that have previously been build into one or more MDBs or System Bases and are awaiting future use in additional MDBs or SBs.

An IDB is organized to provide a set of information related to a basic unit of FSW and or support software data identifiable by its member name.

The data related to member names are stored in a member name implementation data base (MNIDB). The MNIDB contains descriptor data for member names that are such things as programs, procedures, and macros.

6.3.3 Build Control List Data Base

The Build Control List (BCL) data base is used during all system builds (DSB, MDB) as a depository for build progress status data as well as to control the sequencing and activities performed in builds. The BCL data base provides for individual BCLs (one per build) to be created, managed, used, and removed as the build is planned, performed, and reported to the CMDB. Each BCL in the BCL data base is separated from other BCLs both physically and logically so that builds do not interfere with each other. As a part of build preparation for a system, a BCL header segment is created in the BCL data base by the BCL manager transaction. It is under this header segment that the system's BCL will exist when its build occurs.

APPENDIX H

LIST OF INTERVIEWEES

Col. David Mathews, U.S. Army (Retired), Senior Guest Lecturer, Systems Management Department, Naval Postgraduate School, Monterey, California

Professor Norman Schneidewind, Information Systems Engineering and Management Group, Systems Management Department, Naval Postgraduate School, Monterey, California

Professor Carl R. Jones, Information Systems Engineering and Management Group, Systems Management Department, Naval Postgraduate School, Monterey, California

Mr. William Miller, U.S. Army Tactical Air Missile System (ATACMS), Configuration Manager, ATACMS Project Office, SFAE-MSL-AB (South Site/Building 7571), Redstone Arsenal, Alabama 35898-5650

Mr. David C. Schultz, Manager, Management Integration Office/GM, Mail Code MA7, National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, Texas 77058

Mr. William Pruett, Manager, Shuttle Software Development Group, Lyndon B. Johnson Space Center, 2101 NASA Road 1, Houston, Texas 77058-3696

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Mr. Ted Pearson, Department Head, Competency 3.0, Naval Air Warfare Center Training Systems Division, 12350 Research Parkway, Orlando, Florida 32826-3224

Cdr. Thomas Crosby, Deputy Department Head, Competency 3.0.A, Naval Air Warfare Center Training Systems Division, 12350 Research Parkway, Orlando, Florida 32826-3224

LIST OF REFERENCES

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